Department of Conservation and Recreation
Division of Water Supply Protection

Water Quality Report: 2004
Quabbin Reservoir Watershed
Ware River Watershed

Prepared by Department of Conservation and Recreation, Division of Water Supply Protection

June 2005

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ABSTRACT

This report is a summary of water quality monitoring results from thirty-three water quality monitoring stations established throughout the Quabbin Reservoir and Ware River watersheds. The Department of Conservation and Recreation, Division of Water Supply Protection (formerly the Metropolitan District Commission, Division of Watershed Management) is the state agency charged with the responsibility of managing Quabbin Reservoir and its other natural resources in order to protect, preserve and enhance the environment of the commonwealth and to assure the availability of pure water to future generations. As part of this effort, the Environmental Quality Program at Quabbin maintains a comprehensive water quality monitoring program to ensure that Quabbin Reservoir and its tributaries meet state water quality standards. As part of this task, the Environmental Quality Program performs the necessary field work, interprets water quality data and prepares reports of findings. This annual summary is intended to meet the needs of the decision makers, the concerned public and others whose decisions must reflect water quality considerations.

Quabbin Reservoir water quality in 2004 satisfied the requirements of the Filtration Avoidance Criteria established under the EPA Surface Water Treatment Rule. Monitoring of tributaries is a proactive measure aimed at identifying general trends and problem areas that may require additional investigation or corrective action. Compliance with state surface water quality standards among the tributaries varied with minor exceedances attributed to higher pollutant loads measured during storm events, wildlife impacts on water quality, and natural attributes of the landscape.

The appendix to this report includes summary information on mean daily flows of gaged tributaries, water quality data summary tables, plots of reservoir water quality results, and box plots of individual water quality parameters. Some of the ancillary data presented in this report has been compiled with the help of outside agencies and other workgroups inside of the DCR whose efforts have been acknowledged below.

Acknowledgments:

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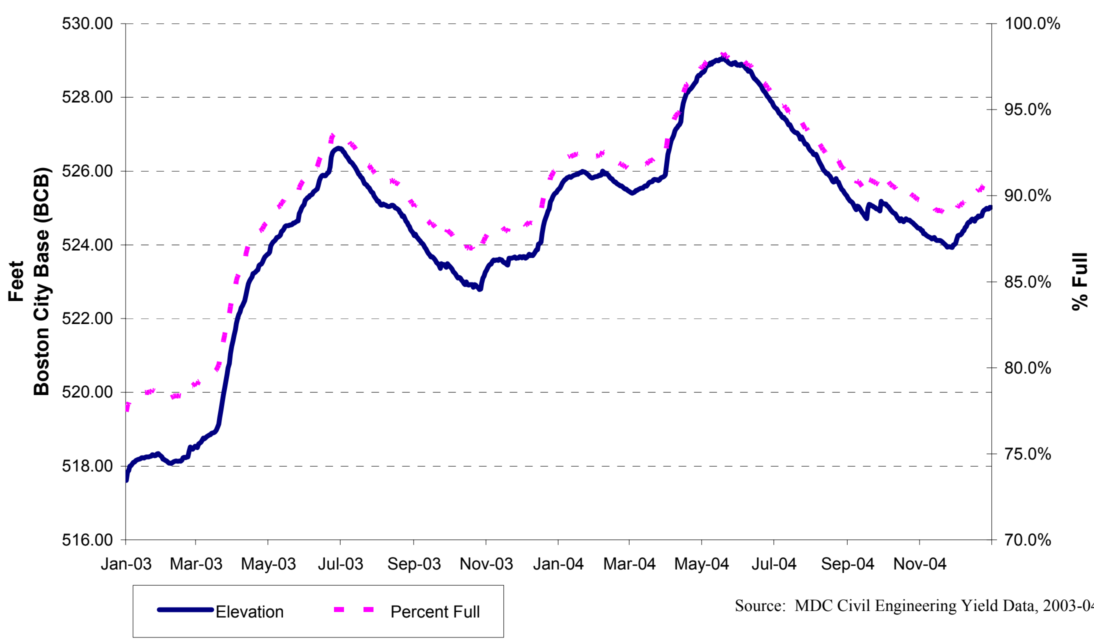
1.0 INTRODUCTION

Figure 2 shows the Quabbin Reservoir, Ware River and Wachusett Reservoir watershed system that supplies drinking water to Boston and 45 other member communities that make up the MWRA service territory. The largest of the three interconnected sources, Quabbin Reservoir, is capable of holding 412 billion gallons of water. Because of Quabbin's size, it required seven years after the damming of the Swift River in 1939 before the reservoir was completely filled. The reservoir surface is best described as two interconnected fingers; the larger eastern finger stretches about 18 miles in length and has a maximum width of roughly 4 miles. The western finger stretches about 11 miles in length and has a maximum width of roughly 1 mile. In total, the reservoir surface area covers 39 square miles (25,000 acres) and contains 118 miles of shoreline. Quabbin Reservoir water transfers to Wachusett Reservoir via the Quabbin Aqueduct Intake at Shaft 12 typically account for more than half of the of MWRA's system supply. In 2004, transfers to Wachusett Reservoir totaled 58,749.68 million gallons. In the 271 days that transfers occurred, the Quabbin Aqueduct delivered an average of 216.8 MGD. A much smaller amount of water is transferred directly to three western Massachusetts communities via the Chicopee Valley Aqueduct at Winsor Dam. In 2004, the CVA Aqueduct delivered on average 8.34 MGD of flow to the CVA communities. The reservoir maintained a normal operating level throughout 2004, continuing what has been steady state of recovery from below normal levels last experienced in early 2003. In 2004, the reservoir had a net loss of 3,675 MG and operating levels experienced a maximum fluctuation of 5.17 feet. Daily fluctuations in reservoir water level during the past two years are depicted in **Figure 1** below.

Figure 1 - Quabbin Reservoir Daily Elevation

01/01/03 – 12/31/04



Source: MDC Civil Engineering Yield Data, 2003-04

Figure 2. Quabbin Reservoir, Ware River and Wachusett Reservoir Watershed System

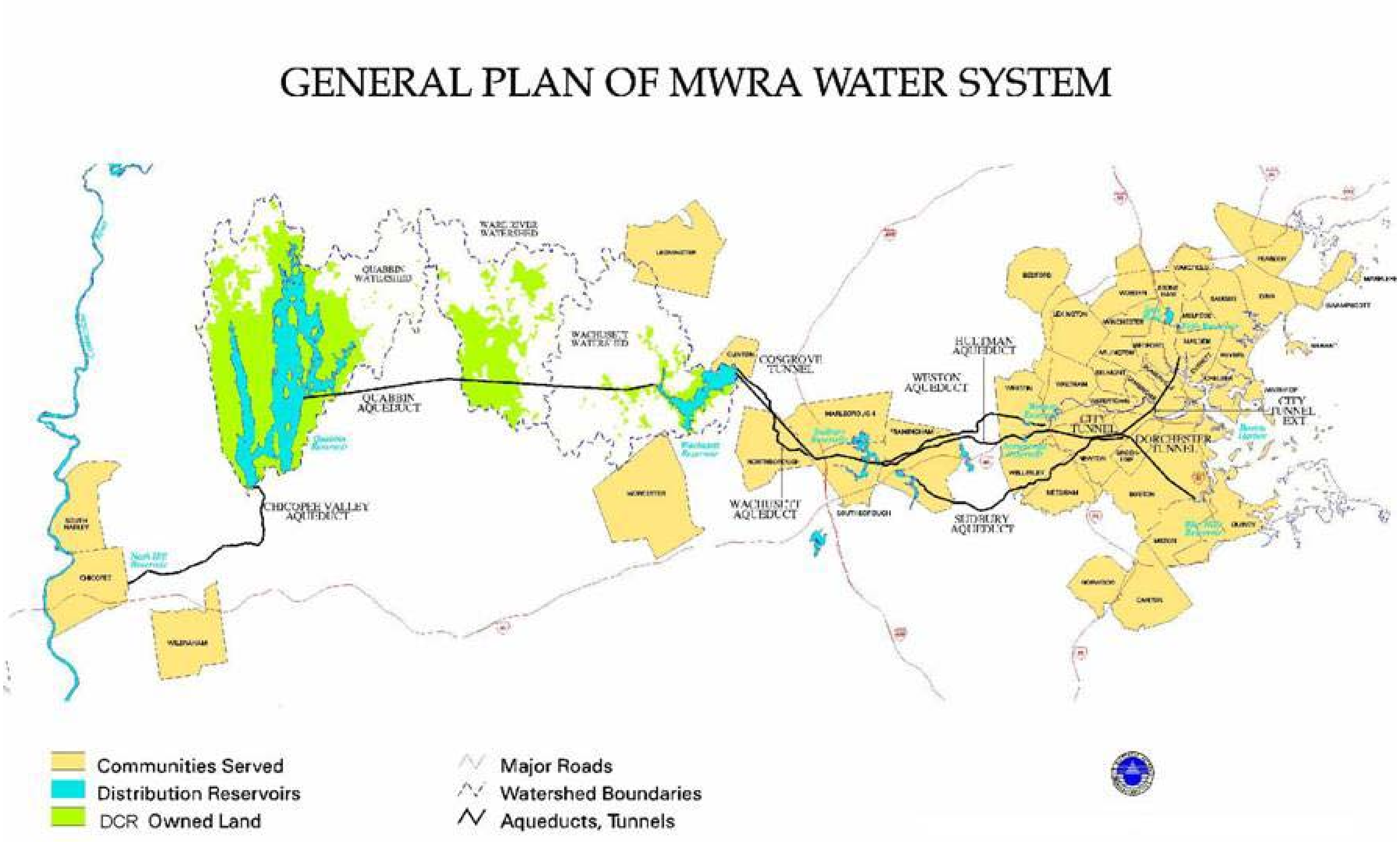


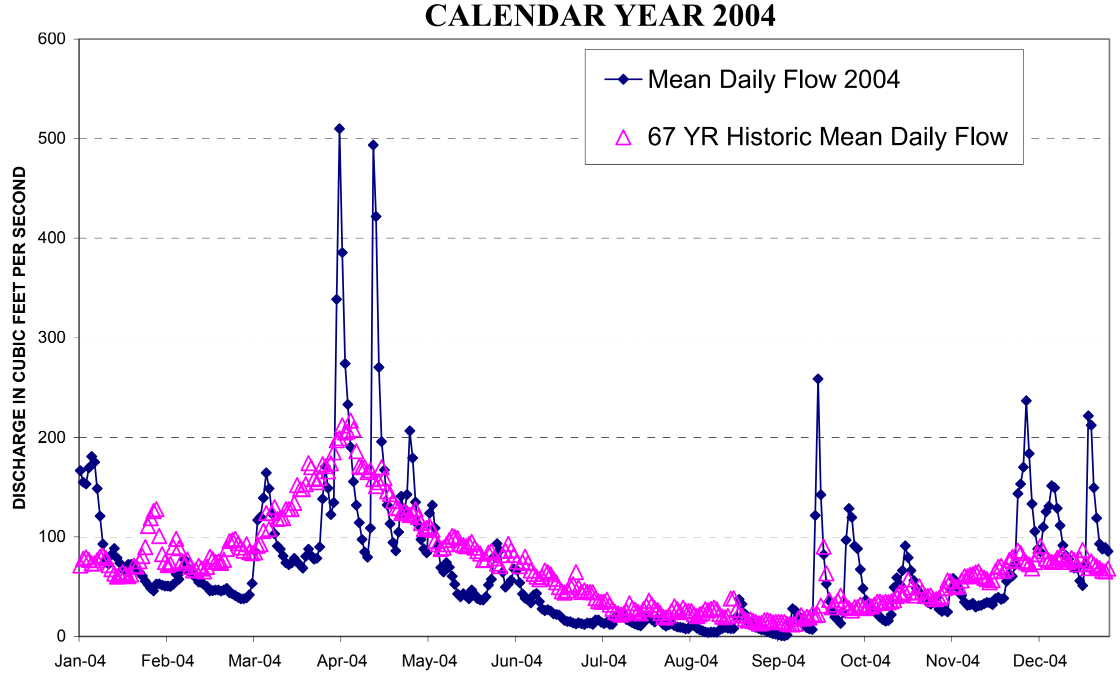
Table 1 - QUABBIN RESERVOIR FACTS AND FIGURES

FACTS ABOUT THE RESERVOIR		FACTS ABOUT THE WATERSHED	
Capacity	412 Billion Gals	**Watershed Area**	120,000 acres
Surface Area	24,000 acres	**Land Area**	96,000 acres
Length of Shore	118 miles	**DCR Owned Land**	53,000 acres
Maximum Depth	150 feet	**% DCR Owned**	55%[1]
Mean Depth	45 feet	**Forested Lands**	83,235 acres
Surface Elevation	530 feet	**Wetlands**	5,289 acres
Year Construction Completed	1939	**Avg. Reservoir Gain From 1" of Precipitation**	1.6 Billion Gallons
Calendar Year:	***2004***	***2003***	***2002***
Maximum Reservoir Elevation (ft)	529.10 on May 19	526.62 on June 29	522.84 on June 13 & 15
Minimum Reservoir Elevation (ft)	523.93 on November 28	517.61 on January 1	516.48 on May 5
Total Diversions to Wachusett Reservoir	58,749.68 MG (271 days: 216.8 MGD)	41,618.7 MG (177 days:235.1 MGD)	60,108.8 MG (269 days: 224 MGD)
Total Diversions to CVA	3,053.8 MG (366 days: 8.34 MGD)	3,029.6 MG (365 days: 8.3 MGD)	3,161.2 MG (365 days: 8.7 MGD)
Ware River Transfers	5,335.8 MG (21 days: 254 MGD)	16,202.8 MG (100 days: 162 MGD)	5,246.2 MG (71 days: 73.9 MGD)
Spillway Discharges	2,417.47 MG (71 days: 34 MGD)	NONE	NONE
Total Diversions to Swift River	11,302.47 MG (30.9 MGD)	9,236.4 MG (25.3 MGD)	12,467.9 MG (34.2 MGD)
Reservoir Ice Cover	≈100% cover: January 22 through April 2 (71 days).	≈100% cover: January 21 through April 7 (76 days).	Full reservoir ice cover not obtained.
Notes: Source: DCR Civil Engineering Yield Data 2002-04 Excludes reservoir surface area. (….) – Denotes number of days and average daily flow.			

The Quabbin Reservoir watershed itself covers 187.5 square miles (120,000 acres) and contains practically all of the towns of New Salem and Petersham, considerable portions of Pelham, Shutesbury, and Wendell, and much smaller portions of Orange, Hardwick, Phillipston, Belchertown, Ware, and Athol. More than 90% of the watershed lands are forested and the Department of Conservation and Recreation owns and controls 53,000 acres (55%) for water supply protection purposes. Non-DCR owned lands can be characterized as sparsely populated and having limited agricultural sites owning to the pristine character often attributed to Quabbin Reservoir water.

The eastern portion of the watershed and much of the Petersham area is drained by the East Branch of the Swift River. This 43.6 square mile subwatershed area is the largest stream tributary to Quabbin Reservoir. The US Geological Survey, Water Resources Division maintains stream gages on the three watershed tributaries: East Branch Swift River in Hardwick, West Branch Swift River in Shutesbury, and the Ware River in Barre. In 2004, mean daily flows for the East Branch Swift River in Hardwick were measured at 67 cfs. No new period-of-station records were established in 2004. **Figure 3** depicts the hydrograph for the East Branch Swift as measured at the horseshoe dam located at the outlet of Pottapaug Pond.

Figure 3 - EAST BRANCH SWIFT RIVER NEAR HARDWICK, MA
CALENDAR YEAR 2004



The western part of the watershed is principally drained by the West Branch of the Swift River. This 14.10 square mile catchment area runs north-to-south between two well-defined, steeply sloped ranges. Steeply sloping ground, shallow soils and a narrow drainage area combine to generate runoff that is extremely quick and stream flows are typically characterized as flashy. In

2004, mean daily flows for the West Branch Swift River averaged 22.9 cfs. In February, mean daily flow averaged 6.9 cfs which established a new monthly minimum period of station record.

Water from Ware River may supplement Quabbin Reservoir supplies by being diverted into the Quabbin Aqueduct at Shaft 8 in Barre and directed west towards Quabbin Reservoir via gravity flow. Under the authority granted by chapter 375 of the Acts of 1926, the DCR is limited in the diversion of the water from the Ware River to a period from October 15 to June 15, and at no time is diversion allowed when the flow of the river at the diversion works is less than 85 MGD. Water from the Ware River enters the reservoir at Shaft 11A, located east of the baffle dams in Hardwick. In 2004, Ware River transfers to Quabbin Reservoir totaled 5,335.8 MG over the course of 21 days. Mean daily flows measured on the river at the intake works in Barre, Massachusetts averaged 149 cfs (96.7 MGD) and no new period of station records were set in 2004.

Watershed runoff for 2004 was generally normal as the US Geological Survey assigned this rating to indexed streams for eight out of the twelve months of the year. Watershed runoff was assigned a below normal rating in February and March. Only during the months of September and December were regional stream flow conditions characterized as above normal. September 2004 was a notably wet month as three tropical storm events crossed the watershed region and contributed to monthly precipitation totals that were 220 percent of normal. Rainfall data is collected at a DCR maintained weather station located west of Winsor Dam. Mean annual precipitation for the Belchertown weather station has averaged 45.89 inches in the 65 years of recordkeeping. In 2004, total precipitation measured 42.34 inches falling in the normal historical range. Precipitation is generally distributed equally throughout the year and a significant portion of it falls as snow. In 2004, snowfall totaled 41.5 inches which fell significantly below the regional annual snowfall average of 60 inches. As evidenced by the stream hydrograph above, most of the surface water runoff occurs during the months of March, April and May and much of this can be explained by springtime snowmelt, returning rainfall precipitation, and an immature tree canopy.

2.0 METHODOLOGY

This report presents water quality data results from routine sampling performed at thirty three surface water monitoring stations located throughout the Quabbin Reservoir and Ware River watershed. There are a number of forces driving the need for a comprehensive water quality monitoring program, and they include:

1) The public health significance associated with the maintenance of long term water quality statistics.
2) To satisfy watershed control criteria applicable to the filtration avoidance requirements stipulated under the EPA's Surface Water Treatment Rule.

3) Identify streams and waterbodies that do not attain water quality standards where specific control measures may be initiated to eliminate or mitigate pollution sources.
4) Proactive surveillance of water quality trends and potential trouble areas.

Sample Station Locations

The thirty-three surface water monitoring stations include all major tributary inflows to Quabbin Reservoir and most minor tributaries flowing to the Quabbin Reservoir or Ware River. The locations of the surface water monitoring stations are depicted in **Figures 4 and 5**. In 2004, thirteen stations were located throughout the Quabbin Reservoir watershed. An additional seventeen tributary stations located in the Ware River watershed are sampled to characterize this supplemental source water supply. Three reservoir stations were also monitored monthly during the months of May thru December. Tables 2 and 3 present drainage area characteristics for the tributary surface water stations.

Data Collection

Each station is sampled biweekly (happening once every two weeks) with sampling runs alternating between the two watersheds. Samples are collected by hand at the beginning of the work week (typically Tuesday) regardless of weather conditions thereby providing a good representation of various flow conditions and pollutant loadings. The frequency of sampling gives a more complete assessment of tributary health as all seasonal flow conditions are represented and both dry and wet weather flows are captured. Tributary stream temperature and dissolved oxygen levels are determined in the field using a YSI Model 57 dissolved oxygen meter.

In CY 2004, Quabbin laboratory staff collected 1,967 source water samples. Of the 1,967 samples; 1,161 were collected for microbial analysis and 806 samples were collected for chemical analysis. Nearly 7,860 individual analyses were performed on these samples and roughly half (3,980) were physiochemical analyses performed at Quabbin laboratory. The analyses were split between physiochemical measurements taken in the field (1,559), chemical analyses performed by DCR staff, and bacterial analyses (2,318) performed by staff from the DCR and MWRA. All records are maintained in permanent bound books and in a digital format (Mircosoft Access database).

Table 2 QUABBIN RESERVOIR TRIBUTARIES
2004 SURFACE WATER MONITORING STATIONS

Tributary	DCR Sample Site #	Sample[1] Frequency	Basin Characteristics		
			Drainage Area (sq. miles)[2]	% Wetland Coverage[3]	% DCR Owned Land[4]
East Br. of Swift River @ Rt. 32A	216	BW	30.3	10.4%	1.7%
West Br. of Swift River @ Rt. 202	211	BW	12.4	3.4%	33.0%
Middle Br. of Swift River @ Gate #30	213	BW	9.14	8.1%	22.7%
East Br. of Fever Brook @ West Road	215	BW	4.15	11.5%	12.3%
West Br. of Fever Brook @ Women's Fed.	215A	BW	2.69	8.9%	18.4%
Hop Brook @ Gate 22	212	BW	4.52	2.5%	32.0%
Rand Brook @ Rt. 32A	216B	BW	2.42	9.9%	22.7%
Atherton Brook @Rt. 202	211A	BW	1.83	3.2%	36.0%
Cadwell Creek @ mouth	211BX	BW	2.59	3.3%	98.0%
Gates Brook @ mouth	Gates	BW	0.93	3.2%	100.0%
Boat Cove Brook @ mouth	BC	BW	0.15	<<1%	100.0%

Notes:

[1]BW = biweekly meaning happening once every two weeks. Prior to May 1990 tributaries were monitored on a weekly basis.

[2]Source: Massachusetts Geographic Information System, Executive Office of Environmental Affairs. Latest revision 3/90.

[3]Source: DEP Wetland Conservancy Program (interpreted from 1:12000 Spring 1992-93 photos, latest revision 4/96).

[4]Source: Automated by Massachusetts Geographic Information System & MDC, latest revision 6/97.

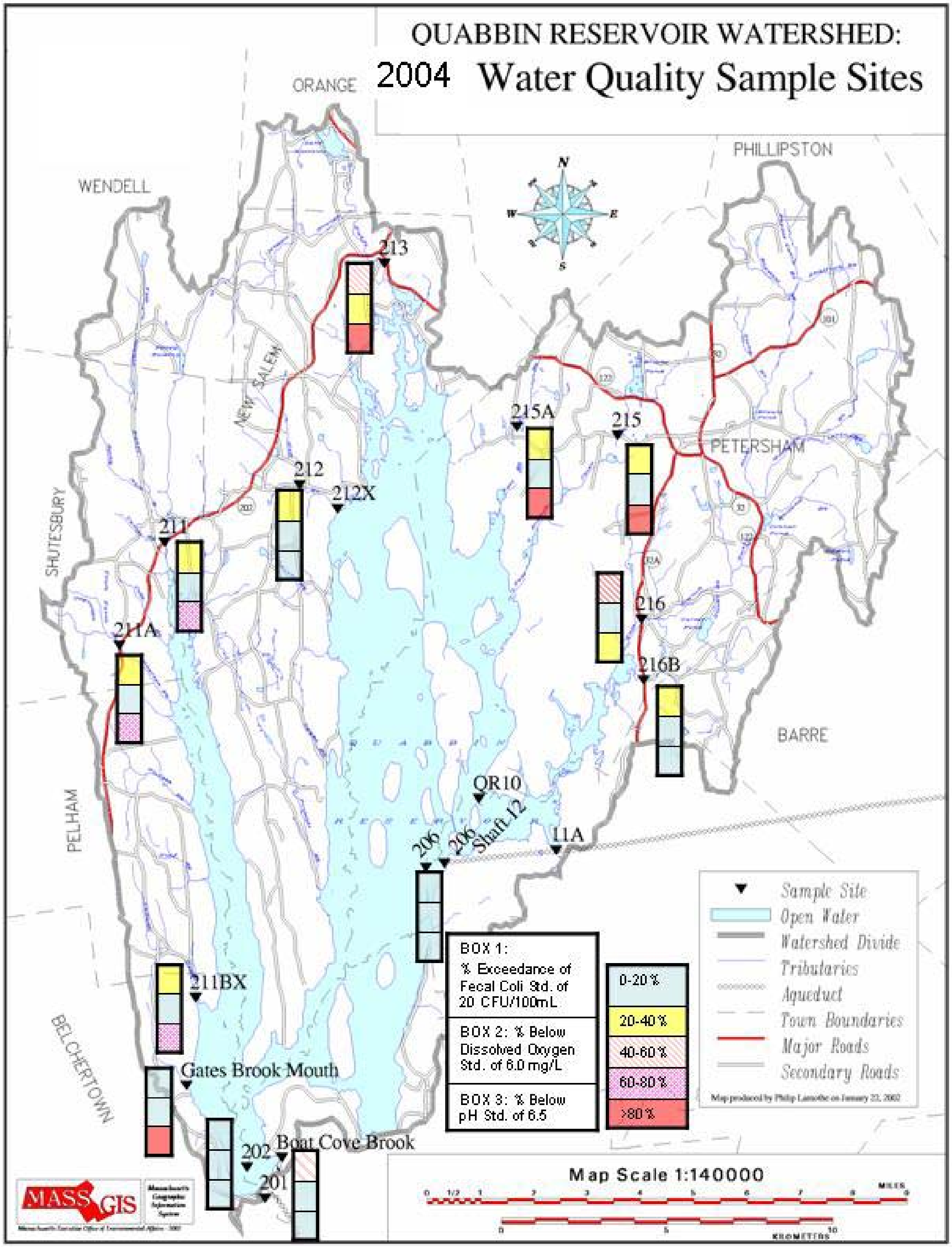


Figure 4 - 2004 Quabbin Reservoir Sample Sites Percent Exceeds Map

Table 3 WARE RIVER TRIBUTARIES
2004 SURFACE WATER MONITORING STATIONS

Tributary	DCR Sample Site #	Sample Frequency[1]	*Basin Characteristics*		
			Drainage Area (sq. miles)[2]	% Wetland Coverage[3]	% DCR Owned Land[4]
Ware River @ Shaft 8 (intake)	101	BW	96.5	13.2%	37.1%
Burnshirt River @ Rt. 62	103	BW	18.4	11.7%	23.5%
Cannesto/Natty @ Rt. 62	104	BW	12.7	8.7%	28.0%
Ware River @ Barre Falls	105	BW	55.1	15.6%	34.5%
Parker Brook @ mouth	102	BW	4.9	9.6%	82.7%
West Branch Ware @ Rt. 62	107	BW	16.6	15.1%	44.9%
East Branch Ware @ New Boston Rd.	108	BW	22.0	16.5%	12.3%
Longmeadow Brook @ mouth	109	BW	12.2	16.5%	47.8%
Long and Whitehall Pond @ outlet	110	BW	5.4	17.8%	37.7%
Queen Lake @ road culvert	111	BW	0.7	36.8%	0%
Burnshirt River @ Williamsville Pond	112	BW	11.4	14.5%	2.5%
Natty Pond Brook @ Hale Road	N1	BW	5.5	14.0%	33.2%
Moulton Pond @ outlet	Moult Pd	BW	1.7	16.4	2.0
Brigham Pond @ outlet	115	BW	11.4	15.4	37.4
Asnacomet Pond @ outlet	116	BW	0.8	29.8	20.9
Demond Pond @ outlet	119	BW	2.3	18.2	14.2
Mill Brook @ Charnock Hill Road	121	BW	3.5	15.5	13.1

Notes:

[1]BW = biweekly meaning happening once every two weeks. Prior to May 1990 tributaries were monitored on a monthly basis.

[2]Source: Massachusetts Geographic Information System, Executive Office of Environmental Affairs. Latest rev. 3/90.

[3]Source: DEP Wetland Conservancy Program (interpreted from 1:12000 Spring 1992-93 photos, latest revision 4/96).

[4]Source: Automated by Massachusetts Geographic Information System & MDC, latest revision 6/97.

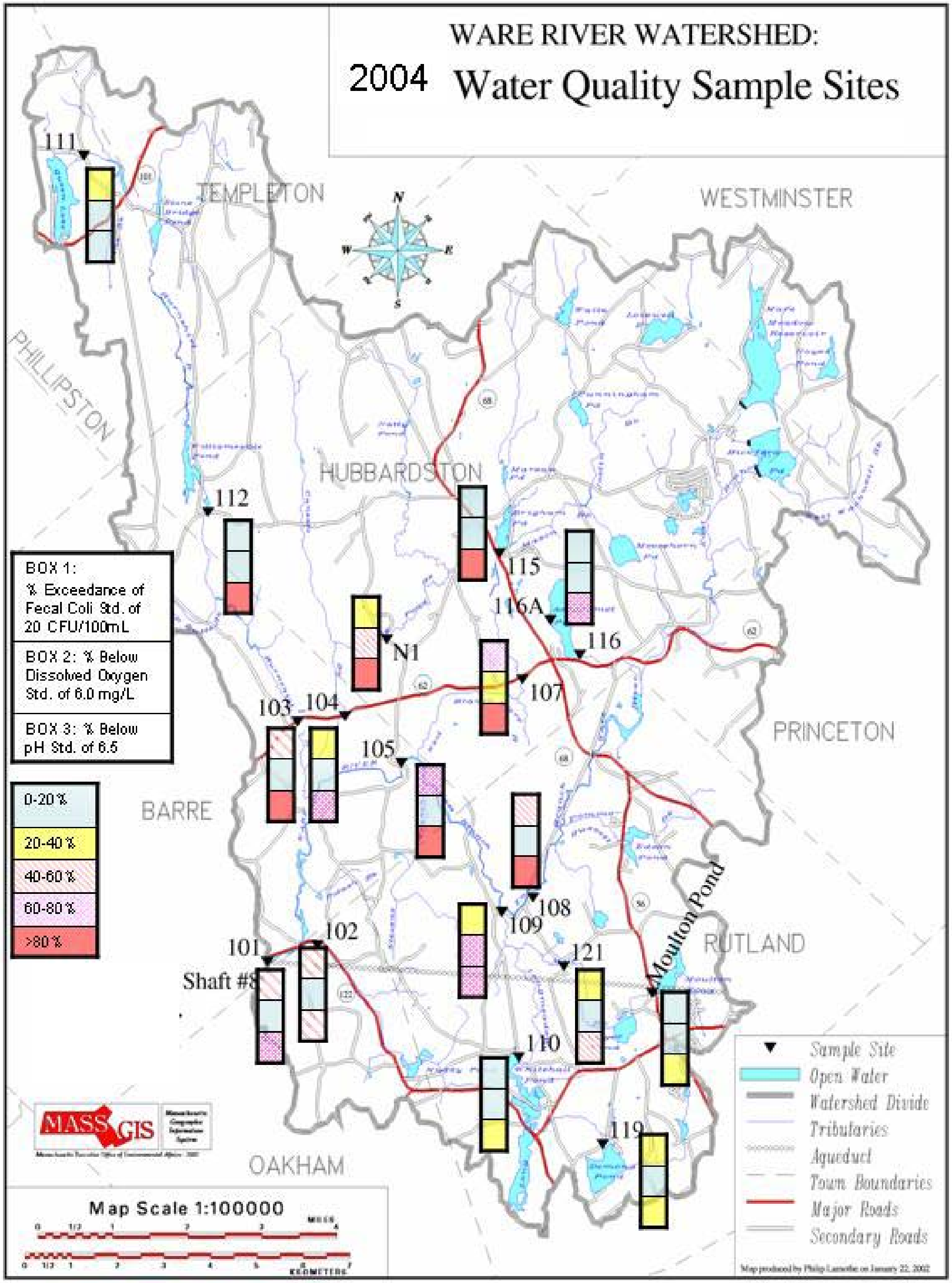


Figure 5 - Ware River Tributary Sample Sites Percent Exceeds Map

Analytical Procedures

Water quality parameters routinely analyzed include temperature, pH, alkalinity, dissolved oxygen, specific conductance, turbidity, total coliform bacteria and fecal coliform bacteria. **Table 2** below lists the equipment and laboratory methods employed at Quabbin laboratory.

Table 4 - QUABBIN LABORATORY: ANALYTICAL AND FIELD METHODS

PARAMETER	**STANDARD METHOD (SM)[1]**
Turbidity	SM 2130 B
pH	SM 4500-H Hydrolab Data Sonde 4a, Orion 811 meter
Alkalinity	SM 2320 B (low level)
Conductivity	HACH DREL/5 meter Hydrolab Data Sonde 4a
Temperature	YSI Model 57 DO Meter Hydrolab Data Sonde 4a
Dissolved Oxygen	YSI Model 57 DO Meter Hydrolab Data Sonde 4a
Total Coliform	SM 9222B
Fecal Coliform	SM 9222
Escherichia coli (E. coli)	EPA Modified mTEC Agar Method

[1]Standard Methods for the Examination of Water and Wastewater, 20th Edition

Measurement Units

Chemical concentrations of constituents in solution or suspension are reported in milligrams per liter (mg/L) or micrograms per liter (μg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit of volume of water (liter). One milligram per liter is equivalent to 1,000 micrograms per liter. Bacteria densities are reported as number of presumptive colony forming units per 100 milliliters of water (CFU/100 mL). The following abbreviations are used in this report:

CFS	Cubic feet per second
CFU	Colony forming unit
MGD	Million gallons per day
NTU	Nephelometric turbidity units
PPM	Parts per million (1 mg/L = 1 PPM)
CU	Color units
TC	Total Coliform
THMFP	Trihalomethane formation potential
TKN	Total Kjeldahl nitrogen
μS/cm	Microsiemens per centimeter
μmhos/cm	Micromhos per centimeter (1 μmhos/cm = 1 μS/cm)

2004 Laboratory Changes

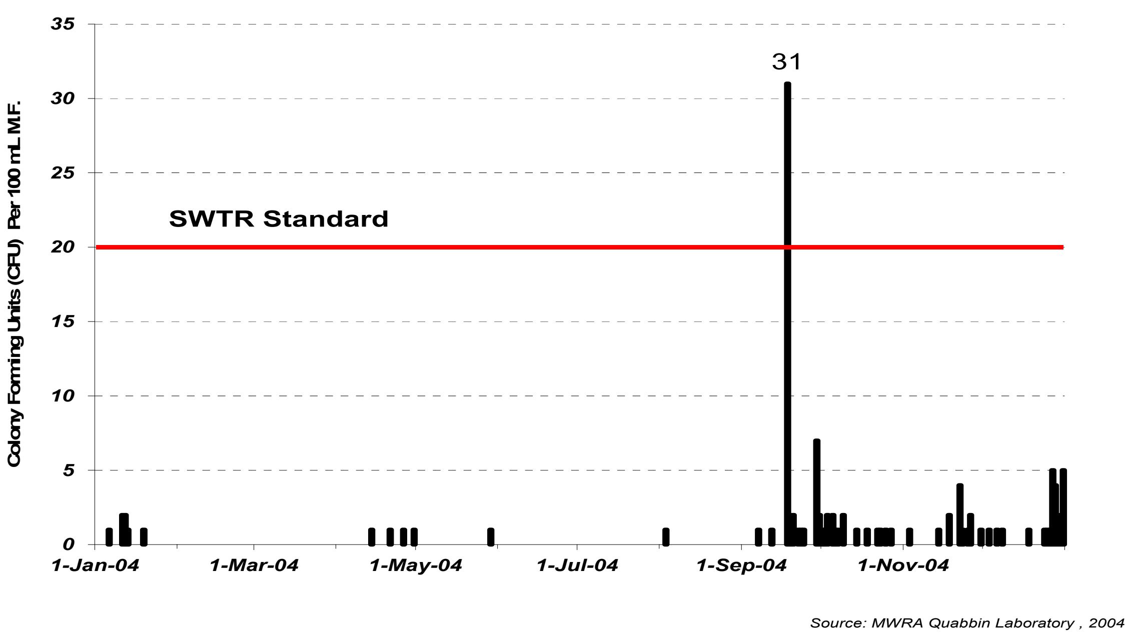
Significant changes were made to the Quabbin laboratory monitoring program in 2004. The most significant change occurred in July 2004 when laboratory responsibilities for all microbiological analyses were transferred from the DCR to the MWRA. The DCR maintained responsibility for all tributary water sample collection and chemical analysis of tributary samples. Other changes in 2004 include:

- Site 201, Winsor Power Station sample site discontinued on July 13, 2004. Quabbin Reservoir source water instead sampled at the Winsor Disinfection Facility at a raw water tap prior to disinfection.
- Monitoring, collection and testing responsibilities for source water compliance purposes was transferred entirely to the MWRA. The MWRA is now solely responsible for daily collection and coliform bacteria analysis of CVA raw and treated water samples. An on-line turbidity meter is maintained at the WDF facility by the MWRA for source water monitoring compliance purposes. The MWRA also performs daily tests on chlorine residual levels and total coliform bacteria on treated water throughout the CVA service line.
- Color was discontinued as a watershed monitoring parameter. Since 1990, color was monitored quarterly at all regular tributary sample stations and monthly at depth at each of the reservoir stations. The purpose of the change was due to a reprioritization of staff time.
- The pH probe on the Hydrolab Datasonde 4a was replaced with a low ionic strength probe in hopes of achieving better consistency between field and in-lab pH measurements.

3.0 RESULTS – SOURCE WATER QUALITY MONITORING

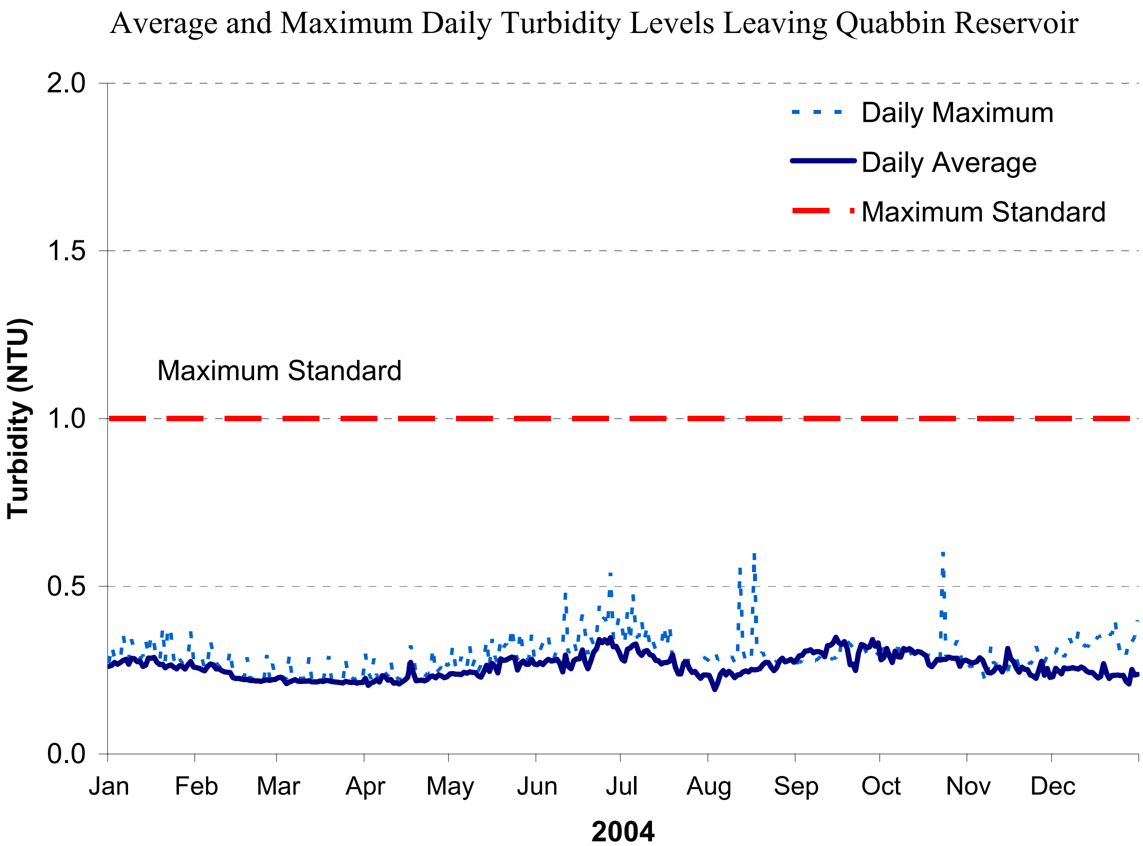
The U.S. EPA promulgated the Surface Water Treatment Rule in 1989 to ensure that public water supply systems using surface waters were providing safeguards against the contamination of water by viruses and other microbial pathogens such as *Giardia lamblia*. The regulations in effect require filtration by every surface water supplier unless strict source water quality criteria and watershed protection goals can be met. Source water quality criteria relies on a surrogate parameter, turbidity, and an indicator organism, fecal coliform bacteria, to provide a relative measure of the sanitary quality of the water. The SWTR standard for fecal coliform bacteria requires that no more than 10% of source water samples prior to disinfection over any six month period shall exceed 20 colonies per 100 mL. To ensure compliance with this requirement, the MWRA monitors daily the bacterial quality of Quabbin Reservoir water at a point prior to disinfection located inside the Winsor Disinfection Station. **Figure 6** depicts daily fecal coliform bacteria levels for 2004 and includes a horizontal line marking the SWTR limit of 20 fecal coliform colonies per 100mL. In 2004, fecal coliform bacteria levels averaged less than one colony per 100 mL and were absent roughly 85% of the time. The SWTR standard of 20 FC/100mL, however, was exceeded on one occasion as a result of Tropical Storm events that preceded the September 18, 2004 exceedance. On the day of the exceedance, water temperatures measured in the CVA prior to disinfection approached 23˚C which indicates that surface waters were mixing with the deeper waters of the hypolimnion. Strong northerly winds that accompanied the storm aided mixing of waters down to the intake depth of roughly 70 feet.

Figure 6. Quabbin Reservoir Source Water Criteria: WDF Fecal Coliform Bacteria Levels Prior to Disinfection



For turbidity, the EPA SWTR standard is 5.0 NTU, but, the Massachusetts DEP has adopted a more stringent performance standard of 1.0 NTU. MWRA monitors turbidity levels prior to disinfection using an on-line turbidity meter located inside the Ware Disinfection Facility. **Figure 7** depicts daily maximum and average turbidity levels for 2004 and includes a horizontal line marking the 1.0 NTU performance standard. For 2004, turbidity levels averaged 0.26 NTU with a maximum value of 0.60 NTU recorded on July 17, 2004.

Figure 7. Quabbin Reservoir Source Water Turbidity (Ware Disinfection Facility)



Giardia and Cryptosporidium monitoring on source water prior to disinfection is also conducted biweekly from a tap located inside the Winsor Power Station. These two waterborne pathogens are of concern because their cysts have a high resistance to chlorine, infectivity doses are low, and life-cycles are longer than conventional microbial pathogens. Both pathogens have been linked to waterborne outbreaks of gastrointestional disorders such as diarrhea, cramping and nausea. Beginning in April 2004, the MWRA began testing samples using the newly established EPA Method 1623 which differs from earlier ICR methods in that only 50 liter samples are collected and the method is about twice as sensitive as earlier methods. Under the new method, identifications are grouped into 3 categories: empty (no internal structures), amorphous (structure not consistent with a normal organism), and one or more internal structures. Test methods still provide no information on the viability of the cysts, but, the MWRA has established a trigger level of 10 cysts/100L above which notification and other actions would be required. Results from 2004 sampling are included in the Appendix. In 2004, Quabbin reservoir source water was absent of cysts with the exception of one positive result for Giardia on November 8, 2004. In that sample one empty cell and one cell containing one or more internal structures was identified.

3.1 RESULTS – RESERVOIR MONITORING

Reservoir water quality data collected by the DCR documents consistently reliable source water quality that fully meets stringent Federal source water quality criteria stipulated under the Surface Water Treatment Rule. Water quality data is collected monthly except during periods of adverse weather and ice conditions in the winter. Three sampling stations that were routinely sampled in 2004 are profiled in **Table 11**. **Figure 4** may be referenced for the specific locations of each sample site.

Table 5 - 2004 QUABBIN RESERVOIR WATER QUALITY MONITORING SITES

Site	***Location***	***Latitude Longitude***	***Approximate Bottom Depth***
Winsor Dam (QR202)	Quabbin Reservoir west arm, off shore of Winsor Dam along former Swift River riverbed.	N 42°17’15” W 72°20’59”	44 meters
Shaft 12 (QR06)	Quabbin Reservoir at site of former Quabbin Lake, off shore of Shaft 12.	N 42°22’11” W 72°16’53”	28 meters
Den Hill (QR10)	Quabbin Reservoir eastern basin, north of Den Hill	N 42°23’23” W 72°15’57”	20 meters

Reservoir water inside the three distinct reservoir basins is sampled at depth monthly between April and December (weather permitting). Water samples are collected at depth with the aide of a kemmerer bottle and samples are analyzed at Quabbin laboratory for turbidity, pH, and alkalinity. Samples for total and fecal coliform bacteria are taken at the surface, mid-epilimnion depth (typically 5-7 meters) and at the respective water supply intake depth. Physiochemical grab samples are taken from mid-epilimnion and mid-hypolimnion during times of thermal stratification, and near the top and bottom during periods of isothermy and mixing. Wind, weather, reservoir conditions and air temperature are recorded on each survey. A standard 20 cm diameter black and white secchi disk is used to measure transparency.

Water column profiles of temperature, pH, dissolved oxygen, and specific conductance are measured “in-situ” using a Hydrolab Data Sonde 4a multiprobe. Readings are taken every meter during times of thermal stratification and mixing, and every three meters during periods of isothermy. Field data is stored digitally in a hand-held Hydrolab Surveyor 4A and transferred to a computer database maintained at Quabbin laboratory.

DCR limnologist, Dave Worden performed quarterly sampling for nutrients and phytoplankton at the onset of thermal stratification (May), in the middle of the stratification period (late July), near the end of the stratification period (October), and during a winter period of isothermy (December). The MWRA Central Laboratory provided analytical support for the measurement of total phosphorous, total kjeldahl nitrogen, nitrate, ammonia, UV_{254} absorbance and silica.

Table 6 presents an overview of reservoir water quality conditions at three stations routinely monitored in 2004. The complete data for individual stations is included in the Appendix. Provided below is a brief discussion of selected monitoring parameters and their significance to reservoir water quality conditions.

Table 7. General Water Chemistry. 2004 Quabbin Reservoir Monitoring Stations.

	pH (Lab)	**Turbidity**	**Dissolved Oxygen**	**Secchi Disk Transparency**	**Total Coliform Bacteria**	**Fecal Coliform Bacteria**
Reservoir Station	Range (units)	Range NTU	Range % Saturation	Range (meters)	Range (CFU/100mL)	Range (CFU/100mL)
Winsor Dam (QR202)	6.0-7.0	0.15-0.3	73-141	6.59-12.6	0-1500	0-1
Shaft 12 (QR206)	5.5-7.0	0.19-0.3	48-149	5.8-13.1	0-176	0-1
Den Hill	6.1-6.9	0.2-0.4	50-134	5.4-7.5	0-62	0-1

Temperature

The thermal stratification that occurs in the reservoir has a profound impact on many of the parameters monitored across the reservoir profile. The temporal zones that develop within the reservoir during the warmer months of spring and summer, known as the epilimnion, metalimnion and hypolimnion (listed in order from top to bottom), have distinct thermal, water flow and water quality characteristics. Waters of the epilimnion are warm and well mixed by wind driven currents, and, may become susceptible to algal growth due to the availability of sunlight and entrapped nutrients introduced to the partitioned layer of surface water. Within the metalimnion the thermal and water quality transition occurs between the warmer surface waters and colder, deep waters. The much deeper hypolimnic waters remain stagnant, have no circulation, and serve as a sink for decaying matter and sediments that settle out from the upper layers of warmer water. Each year the reservoir is completely mixed due the settling of cooler surface waters in the fall and following springtime ice-out when an isothermal water column is easily mixed by winds. Profile data collected at Station 202 is shown in **Figure 8** to graphically portray the thermal mixing and transition that occurs between fully mixed, isothermal to fully stratified conditions. Fall overturn probably occurred during the first week of November as the water column was thermally mixed across more than 90% of the column at Shaft 12 and 75% of the column at Site 202 on November 4th.

Dissolved Oxygen

Oxygen is essential to the survival of aquatic life (trout need a minimum of 5.0 mg/L or 44% saturation at 10°C) and available oxygen also plays an important role in preventing the leaching of potentially harmful metals trapped among the bottom sediments. Dissolved oxygen, or more specifically the loss of oxygen from the hypolimnion, is used is as one index to characterize the trophic state of a lake. Because re-aeration factors such as wind driven turbulence, reservoir currents, and atmospheric diffusion diminish with depth dissolved oxygen concentrations typically decrease with depth. Moreover, the raining down of decaying organic debris into the hypolimnion can be a major source of oxygen depletion in highly productive lakes because of the respiration requirements of microbial populations responsible for the decomposition of organic wastes. Hypolimnic oxygen reserves established in the spring are not replenished until the late fall when cooling surface waters ultimately settle and re-mix the reservoir. In 2004, minimum levels of oxygen reached in the hypolimnion ranged from a low of 48% saturation at the Shaft 12 station to 73% saturation at the bottom depths at Site 202. Depletion levels were most pronounced in the latter stages of stratification (September and October) but levels never dipped below 5.0 mg/L. The seasonal development and breakdown of lake stratification is depicted in temperature and dissolved oxygen profiles shown in **Figure 8**.

Turbidity

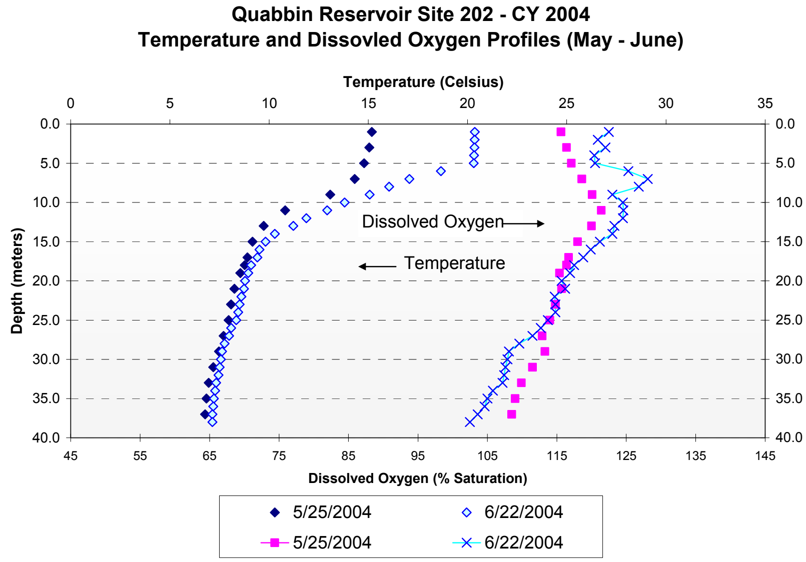
Reservoir turbidity levels are historically very low and stable, reflective of the low productivity of the reservoir. In-reservoir turbidity levels monitored in 2004 ranged from 0.14 to 0.4 NTU. From time to time, algae blooms may impart color and suspended organic particulates that will elevate levels of turbidity. Near-shore areas are also prone to elevated turbidity levels due to the action of waves that may re-suspend shoreline sediment and deposits.

pH and Alkalinity

Three processes principally reflected in reservoir pH and alkalinity dynamics are 1) direct acidic inputs (i.e., rainfall, dry deposition), 2) biological respiration and 3) algal photosynthesis. The input of acid in the form of direct precipitation will consume alkalinity available in the water and reduce pH levels. Reservoir pH is a water quality issue of concern because levels below 6 increase the solubility of persistent heavy metals such as mercury, allowing the metal to be incorporated into the water system and thus more likely to accumulate in the tissue of living organisms such as fish. Quabbin Reservoir and many other northeastern lakes have posted fish consumption advisories that suggest limiting the quantity of fish consumed because of the presence of higher levels of mercury in the fish.

Alkalinity serves as a water body's principal defense by neutralizing the effects of pH. Both pH and alkalinity have a long-term record of stability in the Quabbin Reservoir but levels will fluctuate due to reservoir dynamics. Fluctuations may be caused through respiration by organisms as oxygen is consumed and carbon dioxide is released. The result will be an increase in alkalinity due to the input of carbon to the water. Photosynthetic activity in the epilimnion and metalimnion can decrease alkalinity and increase pH due to the consumption of free carbon dioxide and bicarbonate.

Reservoir water is slightly acidic with pH in the epilimnion slightly higher than the bottom waters. In 46 grab samples collected from the reservoir stations the average pH level was 6.54. Reservoir alkalinity is low and averaged 4.4 mg/L as Ca CO_3 across the three reservoir stations with very little variation observed at depth. In a side-by-side comparison, in-lab measurements of reservoir pH averaged slightly higher than field measurements taken with the Hydrolab Datasonde 4a multiprobe that averaged 6.31. The difference is being attributed to the low ionic strength of Quabbin Reservoir water. In 2004, a new low ionic strength pH probe was installed on the Datasonde 4a in hopes of achieving better consistency between field and in-lab pH measurements.



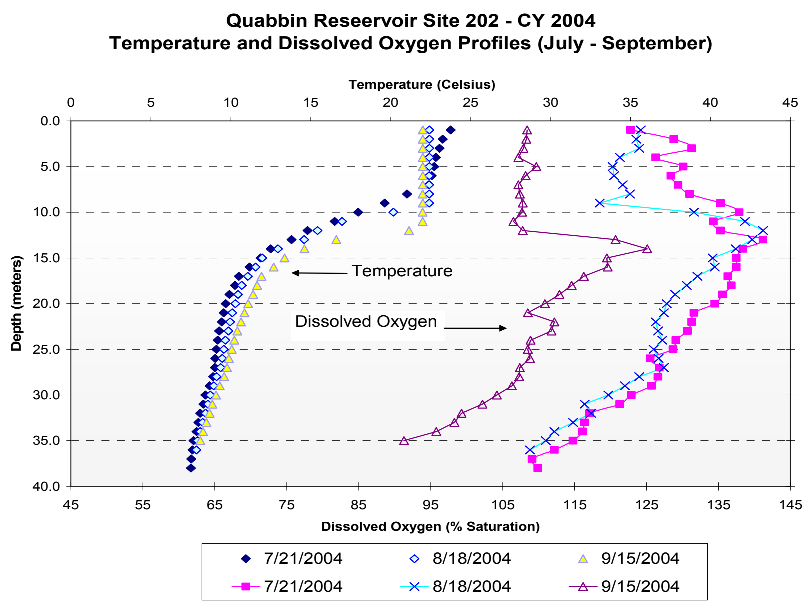
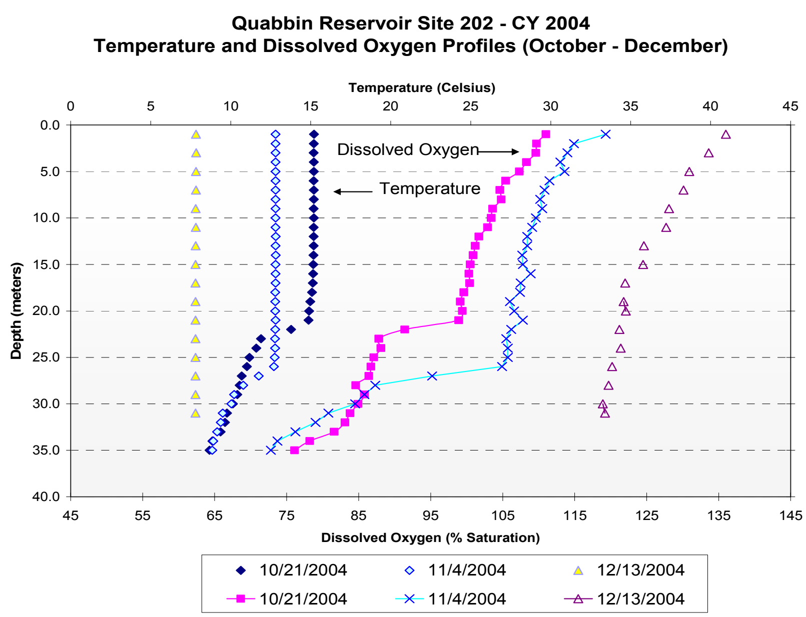


Figure 8

Seasonal variations of temperature and oxygen at depth in Quabbin Reservoir. Station 202, Winsor Dam.



Secchi Disc Transparency

Quabbin reservoir water has excellent clarity and visibility as evidenced by maximum secchi disc readings that approach 13 meters. Transparency is determined as the depth below the surface at which a 20 centimeter black and white disk becomes indistinguishable to the naked eye. Transparency can be greatly influenced by the level of phytoplankton activity but is also sensitive to weather and reservoir conditions at the time of sampling. Historically, reservoir transparency measurements are consistent with the pattern of phytoplankton dynamics (Worden, 2000). In 2004, transparency was measured at a maximum of 13.1 meters at Site 206 on July 22. The Den Hill station is characteristically much lower and reflects the contribution of large, nearby river inputs of the East Branch Swift and Ware River (when diverting). The contribution of the East Branch Swift River, estimated to contribute as much as 9-16% of the annual flow to the reservoir, is a significant source of color that reduces transparency. In 2004, transparency was measured at a minimum of 5.4 meters at Den Hill on May 25 and September 15. Monthly transparency measurements and weather observations are noted in the tables below.

Table 8. 2004 QUABBIN RESERVOIR SITE 202 - WINSOR DAM. SECCHI DISK READINGS WITH WEATHER AND WATER COLUMN OBSERVATIONS.

Date	Transparency (m)	Water Color	Weather Observations
May 25, 2004	10.65	aqua-blue	63˚F and overcast; calm surface with no wind.
June 21, 2004	9.80	aqua-blue	62˚F and sunny; choppy water surface with west wind at 5 mph.
July 22, 2004	12.5	light blue-green	Hazy and hot; slight ripple on surface with wind out of the south at 1-5 mph.
August 18, 2004	12.6	light blue-green	79˚F and mostly sunny; surface ripples with light SSW breeze.
September 15, 2004	10.2	light blue-green	Warm and partly cloudy; surface ripple with light SE wind.
October 21, 2004	6.59	light blue-green	Cool and partly cloudy; one foot waves with a 10-12 mph wind out of the NNE.
November 4, 2004	10.21	light blue-green	Cool and calm; slight surface ripple with a light SW wind.
December 13, 2004	10.6	light blue-green	Cool and cloudy; surface ripples with a light SW wind.

Table 9. 2004 QUABBIN RESERVOIR SITE 206 - SHAFT 12. SECCHI DISK READINGS WITH WEATHER AND WATER CONDITION OBSERVATIONS.

Date	Transparency (m)	Water Color	Weather Observations
May 25, 2004	8.8	aqua-blue	68˚F and cloudy; slight waves with wind at 3mph out of the south.
June 21, 2004	10.0	aqua-blue	72˚F and sunny; choppy water surface with SW wind at 7-12 mph.
July 22, 2004	13.1	light blue-green	Hazy and hot; slight rolling waves with wind out of the south at 1-5 mph.
August 18, 2004	11.1	light blue-green	77˚F and mostly sunny; surface ripples with light SSW breeze.
September 15, 2004	9.6	light blue-green	Warm and partly cloudy; surface ripple with light wind out of the south.
October 21, 2004	5.8	light blue-green	Cool and cloudy; choppy surface with a 6-8 mph wind out of the NNE.
November 4, 2004	8.32	light blue-green	Cool and calm; slight surface ripple with a light SW wind.
December 13, 2004	8.9	light blue-green	Cool and cloudy; wavy surface with a SW wind at 5-10 mph.

Table 10. 2004 QUABBIN RESERVOIR SITE DEN HILL. SECCHI DISK READINGS WITH WEATHER AND WATER CONDITION OBSERVATIONS.

Date	Transparency (m)	Water Color	Weather Observations
May 25, 2004	5.4	yellow-green	75˚F and cloudy; calm surface with very slight southerly wind at 1 mph.
June 21, 2004	5.6	green	74˚F and sunny; 4" waves with SW wind at 7-12 mph.
July 22, 2004	7.0	green	Hazy, hot and humid; slight rolling waves with wind out of the south at 1-5 mph.
August 18, 2004	7.5	green	78˚F and hazy sun; slightly wavy surface with light southerly breeze.
September 15, 2004	5.4	light yellow-brown	Warm and partly cloudy; surface ripple with light wind out of the southwest.
October 21, 2004	No Data	No Data	No Data Available.
November 4, 2004	6.65	light yellow-brown	Cool and calm; calm surface with a slight SW wind.
December 13, 2004	6.7	light yellow-brown	Cool and cloudy; choppy surface with a SW wind at 3-5 mph.

Coliform Bacteria

In-reservoir coliform bacteria levels were monitored at the routine reservoir stations monthly beginning on May 25 and ending on December 13. During periods of thermal stratification, grab samples were collected from the surface, at the five meter depth, and from the respective water supply intake depth at the two deep basin sites (Shaft 12 and Winsor Dam). The term coliform is used to describe a group of bacteria based on biochemical functions and not on taxonomy. For instance, by using selective culturable media and incubation temperatures it is easy to differentiate between the total and the fecal coliform groups. Taxonomically, the two groups are very different; unlike total coliform bacteria, fecal coliform bacteria are normal inhabitants of the intestine of warm blooded animals and humans. Moreover, normally parasitc forms of the fecal coliform group do not survive more than an order of weeks in reservoirs, streams and the open environment while bacteria of the total coliform group are natural inhabitants of the aquatic system and the environment. For these reasons, fecal coliform bacteria are the preferred choice as indicators of fecal pollution because their presence usually indicates recent pollution of the water.

Fecal coliform bacteria levels in reservoir samples are very low having ranged from zero to one colony per 100 mL in 2004. A seasonal gull population that roosts on the reservoir overnight has been identified as the primary contributor of fecal coliform bacteria contamination to the reservoir. Other sources may include other waterfowl, semi-aquatic wildlife and tributary inputs. However, because of the long residence time of the reservoir (reported on the magnitude of several years), fecal coliform bacteria levels are normally very low reflecting die-off and predation that occurs naturally.

Reservoir total coliform bacteria are much more dynamic having ranged from zero to 1,500 colonies per 100 mL in 2004. Currently, a lack of a clear understanding of the natural microbial flora of the reservoir and a poor correlation of total coliform levels with reservoir fecal coliform levels makes fecal coliform the indicator of choice for tracking contamination purposes. This approach is consistent with the EPA Surface Water Treatment Rule finding which specified that when both total and fecal coliform bacteria are analyzed the fecal findings have precedent.

Reservoir Phytoplankton and Nutrient Dynamics

The nutrient database for Quabbin Reservoir established in the 1998-99 year of monthly sampling and subsequent quarterly sampling through 2003 is used as a basis for interpreting data generated in 2004 (see Table 11). Results of quarterly nutrient sampling in 2004 document concentrations and intensities that register almost entirely within historical ranges.

The only parameter with values significantly higher than historical ranges is total phosphorus with two values measured in May appearing elevated. Specifically, these values were reported in the epilimnion at Winsor Dam/Station 202 and in the hypolimnion at Mt. Pomeroy/Station 206 (see Table 11). It is not clear if these results were a function of limits in laboratory analysis precision which has produced coefficient of variations in phosphorous duplicate sampling that average 22.3% and can range as high as 110% (Worden, 2000).

In general, the patterns of nutrient distribution in 2004 quarterly samples were comparable to those documented previously in the 2000 report on Quabbin nutrient and plankton dynamics. These patterns consist of the following: (1) prominent seasonal and vertical variations due to demand by phytoplankton in the trophogenic zone (low concentrations in the epilimnion and metalimnion) and decomposition of sedimenting organic matter in the tropholytic zone (higher concentrations accumulating in the hypolimnion), (2) a lateral gradient in silica concentrations correlated to hydraulic residence time and mediated by diatom population dynamics, (3) and slightly higher concentrations and intensities at the Den Hill monitoring station due to the loading effects of the East Branch Swift River.

Table 11 - Quabbin Reservoir Nutrient Concentrations:

Comparison of Ranges from 1998-03 Database[1] to Results from 2004 Quarterly Sampling[2] (Worden, 2004)

Sampling Station [3]	Ammonia (NH3; ug/L)		Nitrate (NO3; ug/L)		Silica (SIO2; mg/L)		Total Phosphorus (ug/L)		UV254 (Absorbance/cm)	
	1998-03	Quarterly'04	1998-03	Quarterly'04	1998-03	Quarterly'04	1998-03	Quarterly'04	2000-03	Quarterly'04
WD/202 (E)	<5 - 16	<5 - 5	<5 - 23	<5 - 15	0.84 - 1.73	1.43 - 1.82	<5 - 12	5 - 20	0.017 - 0.025	0.021 - 0.024
WD/202 (M)	<5 - 29	<5 - 7	<5 - 27	<5 - 16	0.83 - 1.79	1.39 - 1.78	<5 - 13	7 - 12	0.017 - 0.027	0.022 - 0.027
WD/202 (H)	<5 - 53	<5 - 26	<5 - 54	14 - 34	1.08 - 2.58	1.72 - 2.15	<5 - 44	6- 10	0.017 - 0.024	0.022 - 0.023
MP/206 (E)	<5 - 8	<5	<5 - 20	<5 - 12	0.84 - 1.52	1.31 - 1.62	<5 - 12	<5 - 8	0.017 - 0.025	0.022 - 0.031
MP/206 (M)	<5 - 34	<5	<5 - 44	<5 - 13	0.84 - 1.56	1.28 - 1.56	<5 - 9	<5 - 12	0.017 - 0.029	0.022 - 0.029
MP/206 (H)	<5 - 105	<5 - 19	<5 - 29	6 - 95	1.02 - 1.92	1.49 - 1.92	<5 - 12	<5 - 19	0.018 - 0.026	0.022 - 0.024
Den Hill (E)	<5 - 19	<5 - 13	<5 - 45	<5 - 21	0.74 - 4.64	1.00 - 2.41	<5 - 15	<5 - 9	0.025 - 0.112	0.032 - 0.065
Den Hill (M)	<5 - 25	<5 - 12	<5 - 58	<5 - 12	0.84 - 4.37	1.22 - 2.39	<5 - 15	<5 - 10	0.027 - 0.090	0.036 - 0.060
Den Hill (H)	<5 - 84	12 - 21	<5 - 74	9 - 78	0.83 - 4.25	1.76 - 3.31	<5 - 15	<5 - 13	0.028 - 0.103	0.045 - 0.071

Notes: (1) 1998-03 database composed of 1998-99 year of monthly sampling and subsequent quarterly sampling conducted through December 2003, except for measurement of UV254 initiated in 2000 quarterly sampling

(2) 2004 quarterly sampling conducted May, August, November, and December

(3) Water column locations are as follow: E = epilimnion/surface, M = metalimnion/middle, H = hypolimnion/bottom

3.2 RESULTS - TRIBUTARY MONITORING

Monitoring of tributary water quality is not required by the SWTR or other regulations but does serve to establish a baseline of water quality data from which trends may be used to identify subwatersheds where localized activities may be adversely impacting water quality.

Fecal Coliform Bacteria

2004 median fecal coliform bacteria levels at all stations fell within normal historic ranges (1990-2003) and most fell below the Class A Standard of 20 FCU/100mL. Sites with median levels at or above the Class A standard were Barre Falls Dam, West Branch Ware River, Ware River at Shaft 8, Longmeadow Brook and Boat Cove Brook (listed in order from highest to lowest). New historic maximum levels were recorded at three of the twenty-one stations: three caused by Tropical Storm Jeanne on September 28 at the East Branch Swift, Atherton Brook and the Boat Cove Brook.

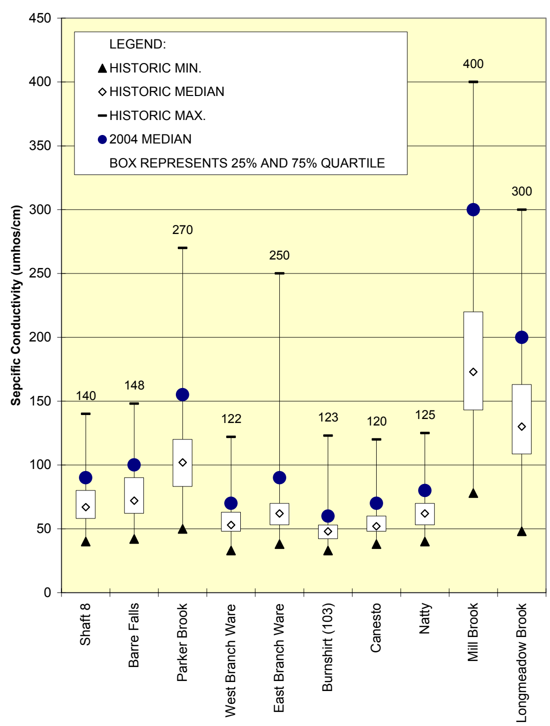
Total Coliform Bacteria

2004 median total coliform bacteria levels exceeded the historic 75% quartile level at all but three of the tributary monitoring stations: Atherton Brook, Gates Brook and the Boat Cove Brook. New historic maximum levels were recorded at eight of the twenty-one stations: six recorded after the remnants of Tropical Storm Jeanne dumped up to 2.44 inches of rain on September 28, one recorded on July 8 at the West Branch Swift, and one recorded on August 10 at Longmeadow Brook.

Specific Conductance

Median specific conductance levels are on the increase at most all watershed stations and correlations with road densities seems to suggest that increasing use of de-icing salts is responsible for this apparent trend. Specific electrical conductance is the measure of the ability of water to conduct an electrical current, which is dependent on the concentration and availability of mineral ions. Elevated levels in streams may be indicative of contamination from septic system effluent, stormwater discharges or agricultural runoff. One significant source of higher levels in tributaries is chloride found in deicing salts applied to highways and local roads. 2004

Figure 9. Annual Median Specific Conductance Levels in Ware River Tributaries Verses Historic Levels (1990-2003).



median specific conductance levels exceeded historic 75% quartile levels (1990-2003) at all of the Ware River tributaries (Figure 9). A similar trend is apparent in Quabbin Reservoir tributaries with the exception of three tributaries whose catchment areas are comprised of mostly gravel roadways. Quabbin tributaries whose 2004 median levels were essentially unchanged from historic levels include the West Branch Swift River, Atherton Brook, Gates Brook and the Boat Cove Brook. These tributaries share the fact that road densities are low and most of the roads inside the catchment areas are gravel surface roads where the application of road salt (if any) is expected to be reduced because of slower travel speeds and the rural character of these roads.

Dissolved Oxygen

The oxygen concentration of tributaries of Quabbin Reservoir and Ware River watershed were generally quite high. Concentrations ranged between 1.81mg/L and 16.59 mg/L. The source of dissolved oxygen in a stream environment comes from re-aeration dynamics. Dissolved oxygen levels are depleted though the oxygen requirements of aquatic life, the decomposition of organic matter, and the introduction of foreign oxygen-demanding substances (i.e. chemical reducing agents). Temperature, stream flow, water depth and the physical characteristics of the stream channel are the principal drivers of re-aeration. The Massachusetts Class A standard is a minimum of 6.0 mg/L.

Temperature

Temperature in tributaries of Quabbin Reservoir and Ware River watershed ranged between zero and 24.3˚C. Temperature is an important parameter in its relation to dissolved oxygen because as temperature increases the amount of oxygen that can be dissolved in water decreases. Moreover, higher temperatures increase the solubility of nutrients and may correlate well with an increase in the growth of filamentous green algae

Turbidity

Turbidity is the relative measure of the amount of light refracting and absorbing particles suspended in the water column. Turbidity is used as an indicator of water aesthetics and as a relative measure of the water's productivity. The Massachusetts drinking water standard is 5 NTU for source water and 1 NTU for finished water. Median 2004 turbidity levels exceeded the 1 NTU standard at seven of twenty-one tributary monitoring stations: Ware River at Shaft 8, Parker Brook, Ware River at Barre Falls, East Branch Ware River, Mill Brook, Longmeadow Brook and Hop Brook. The highest turbidity level recorded was 5.5 NTU measured at the East Branch Ware River on June 1 and at the Barre Falls Dam on June 29.

pH

Stream acidity is largely a function of the groundwater hydrogeology of the basins and their effectiveness in buffering the effects of acid precipitation. pH is a measure of the number of hydrogen ions [H+] reported on a log scale of 0 to 14. An [H+] concentration of 7.0 represents neutral water and levels below this are considered acidic with each drop in one unit representing a 10 fold increase in acidity. Median pH values in 2004 were below the Class A water quality threshold of 6.5 units at 17 of 21 monitoring stations. The four tributary stations whose median pH values were at or above the Class A standard were the East Branch Swift River, Hop Brook, Boat Cove Brook, and Mill Brook.

Alkalinity

Alkalinity is a relative measure of water's ability to neutralize an acid. Median alkalinity (standard method) levels in 2004 were below the ARM endangered threshold value of 5 mg/L as $CaCO_3$ at eleven of twenty-one tributary monitoring sites. At three stations, Gates Brook, Atherton Brook, and Williamsville Pond, average April levels were classified as critical under criteria established by the Acid Rain Monitoring Project at the University of Massachusetts.

Ware River Watershed Ponds and Lakes

Routine monitoring sites are established at the outlet of six ponds located in the Ware River Watershed. The location of these pond stations is shown in **Figure 5** and pond characteristics are profiled in **Table 12**. Whitehall and Long Ponds are DCR owned ponds with their shorelines virtually undeveloped with the exception of a Mass Highway maintenance garage and salt shed that sits on the banks of the middle basin. The larger ponds (i.e. Asnacomet, Queen Lake, and Demond Pond) have 50% or more of their shorelines developed with seasonal and summer homes. The smaller ponds, Moulton and Brigham Pond, have very little of their shoreline developed. Small, public beaches are maintained on Whitehall Pond, Asnacomet Pond, Brigham Pond and Queen Lake. Public boat ramps are located on Long Pond, Demond Pond, Asnacomet Pond, Queen Lake, and Brigham Pond. A gravel pull-off area off of Route 56 serves as an informal access point to Moutlon Pond.

Surveys of aquatic vegetation last performed in 1998 as part of the Department of Environmental Protection's Pond and Lakes Program quantified areas of dense coverage and identified any exotic species present. Long Pond was estimated to have between 25 and 60 percent of its open water habitat loss to choking aquatic vegetation. The next highest percentage of aquatic vegetation was estimated at 20% at Moulton Pond. Invasive non-native plant species that include Purple Loosestrife (Lytrum Salicearia) and Water Milfoil (Myriophyllum heterophyllum) were identified at Long Pond while Phragmites was identified at Moulton Pond. Among the other ponds surveyed, isolated dense stands of vegetation were observed near to the boat ramps and in isolated coves at Brigham Pond and Demond Pond. Occurrences of dense aquatic vegetation at Queen Lake and Asnacomet Pond were rare or not observed at all.

Table 12. Ware River Watershed Ponds and Lake Monitoring Sites.

	Site #	Location	Surface Area (acres)	Shoreline Development Ratio	Max Depth (feet)	Shoreline (feet)
Asnacomet Pond	116	Hubbardston	127	1.6	52	13,416
Queen Lake	111	Phillipston	134	1.92	22	16,250
Demond Pond	119	Rutland	119	1.51	27	12,120
Long Pond / Whitehall Pond	110	Rutland	81 / 25	5.5 / 2.2	25 / 12	36,734 / 7,979
Moulton Pond	Moult.	Rutland	64.8	0.57		3,397
Brigham Pond	115	Hubbardston	63	2.1	11	12,497

Notes:
Shoreline Development Ratio = Length of Shoreline / Circumference of Circle of Same Area

Historical averages of water quality data from 1990 through 2003 from these monitoring sites is presented in Table 13. Results show that the ponds have slightly acidic water, are of low tuirbidity, and low bacterial activity. The data also shows that water quality is stable with no obvious long term trends with the exception of an increasing trend of specific conductivity in each of the ponds located in Rutland. A decreasing trend in dissolved oxygen among the Rutland Ponds is likely related as dissolved salts lower the amount of oxygen that can be dissolved in water. This apparent trend might reflect landscape changes that have occurred within the Rutland area as a result of urban development pressures.

Table 13. Comparison of Ranges for Ware River Watershed Pond Monitoring Sites.

	pH (Lab)		Turbidity		Dissolved Oxygen (mg/L)		Specific Conductivity (umhos/cm)		Fecal Coliform Bacteria (CFU/100mL)	
Pond Station	Range 1990-03	Range 2004	Range 1990-03	Range 2004	Range 1990-03	Range 2004	Range 1990-03	Range 2004	Range 1990-03	Range 2004
Asnacomet Pond (116)	5.9-6.72	6.01-6.61	0.2-1.5	0.2-0.55	6.1-16.3	7.25-14.6	30-40	30-45	0-110	0-26
Queen Lake (111)	6.0-6.99	6.39-6.80	0.23-3.3	0.4-2.00	7.0-16.8	8.13-14.6	42-112	55-100	0-1520	0-365
Demond Pond (119)	5.7-7.13	6.30-7.10	0.25-1.3	0.35-2.00	5.6-14.2	6.01-14.2	50-140	100-210	0-460	0-54
Long/Whitehall Pond (110)	5.7-7.1	5.95-6.90	0.3-3.0	0.4-2.00	5.12-13.5	6.05-12.0	93-300	200-400	0-152	0-200
Moutlon Pond	5.9-7.06	6.11-7.00	0.4-3.0	0.55-2.55	2.2-13.9	5.44-14.5	73-470	165-350	0-250	0-29
Brigham Pond (115)	5.2-6.6	5.40-6.70	0.3-5.0	0.55-2.00	2.9-17.2	5.86-14.2	32-70	44-60	0-980	0-205

4.0 PROPOSED SCHEDULE FOR 2005

The Quabbin Reservoir sampling program for 2005 will shift focus away from sites with sufficient long term historical data to sites used to support Environmental Quality Assessments. The changes described below are significant but mark the first significant change in the sampling program in ten years. The collection of additional water quality data is being proposed in an attempt to address issues raised in previous research efforts conducted by the University of Massachusetts at Amherst and to help further our understanding of the reservoir and its tributaries.

The tributary sampling program will maintain five long-term, "core" sites located on primary tributaries inside of each watershed (Quabbin and Ware River). These core sites are important because they capture significant flow information and long term historical data will continue to be maintained. Within the Quabbin Reservoir watershed, sites will be added for Environmental Quality Assessment purposes on the West Branch Swift River (3), Middle Branch Swift River (2) and Hop Brook (2). In addition, two sites (Boat Cove, Gates Brook) located inside the Pathogen Control Zone will continue to be monitored for surveillance purposes. Sites to be discontinued include Cadwell Creek, Atherton Brook, West Branch Fever Brook, and Rand Brook.

For the Ware River watershed, sites will be added for EQA purposes on the East Branch Ware River (3) and below Comet Pond outlet (1). Three existing sites will be replaced with "core" sites to be located downstream: the new sites include Burnshirt River at Riverside Cemetery, Thayer Pond outlet, and the West Branch Ware River at Brigham Road. Sites to be discontinued include Queen Lake, Burnshirt River at Williamsville Pond, Burnshirt River at Route 62, Natty Pond Brook, Brigham Pond, Demond Pond, Moulton Pond, Whitehall Pond, Longmeadow Brook, Mill Brook, Canesto and Natty Brook at Route 62, and Parker Brook.

Water quality parameters that will be monitored biweekly by staff at the Quabbin laboratory will include total coliform bacteria and fecal coliform bacteria. Biweekly readings of pH, specific conductivity, dissolved oxygen and temperature will be taken in the field at each sample site using a multiprobe unit. Quarterly nutrient samples will be collected from the "core" tributary stations with more frequent (biweekly) sampling occurring on EQA sites. All nutrient samples will be analyzed by MWRA staff located at the Deer Island laboratory. Alkalinity will be monitored on a biweekly basis at EQA sites where historical data is lacking or where levels have been historically at or below critical Acid Rain Monitoring project levels. In the Ware River watershed, UV_{254} levels will be monitored biweekly on all tributary samples with the exception of Site 101 (Ware River at Shaft 8), which will be monitored on a weekly basis.

Sampling on the reservoir will remain virtually unchanged. In 2005, the Quabbin Reservoir sites at the shore of Shaft 12 and Shaft 11A will be discontinued. Sampling at the three deep-water reservoir stations will remain unchanged with temperature, dissolved oxygen, pH and conductivity profiles collected monthly. The reservoir nutrient and phytoplankton sampling program that has been conducted quarterly since 2000 will be continued in 2005. In 2005, frequent (weekly) secchi disk readings are being recommended in an attempt to better target available resources associated with sampling of phytoplankton and nutrient dynamics of Quabbin Reservoir.

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APPENDIX A

Investigative Reports:

High Fecal Counts at the CVA

Comet Pond Beach

Reservoir Nutrient Sampling

Giardia/Cryptosporidium Results

High Fecal Coliform Counts at the CVA (9/18 and 9/29 2004)

Two episodes of high fecal coliform (FC) counts were experienced in the month of September 2004 at the Chicopee Valley Aqueduct (CVA). On September 18, on a sample collected at 8:00 AM, the count reached 31 FC, while on September 29 the count reached 7 FC. Both of these episodes were rare for two reasons. First, since January of 1994 but prior to September 18, only 19 other times had the counts been seven or above. Second, all of those 19 episodes occurred after the start of the Gull Season at the Quabbin Reservoir, which generally runs from the end of October through the middle of March, suggesting that that FC counts are influenced by the arrival of large numbers of seagulls at the reservoir. See chart below.

High Fecal Coliform Counts since 1/1/1994

Date of Occurrence	Fecal Coliforms (CFU/100 Ml)
12/29/94	7
10/30/95	7
1/29/96	7
1/30/96	7
2/1/96	7
12/17/02	7
1/11/03	7
11/2/94	8
11/12/95	8
1/24/97	8
1/3/02	8
1/28/96	9
1/29/96	9
1/10/03	9
12/30/94	10
4/1/01	15
4/3/97	16
12/12/02	21
12/29/94	25

Therefore, the fact that the two episodes of 2004 occurred a month before the usual start of the Gull Season seemed to indicate that other factors might be driving FC counts. So, the Environmental Quality Section (EQ) at Quabbin undertook a series of steps to try to determine what caused the high counts.

The first step taken was a series of sampling events at the mouth of rivers and brooks emptying to see if any of them had abnormally high FC counts and be driving up the counts at the CVA. However, none of the samples analyzed showed anything out of the ordinary. However, the results of routine sampling at Boat Cove Brook on September 27 showed FC counts in the thousands. This particular sample was taken immediately after more than three inches of rain fell in the area, and therefore the source of the FCs were thought to be the beaver ponds upstream on Boat Cove Brook.

To see if this was the driver for the high CVA counts, sampling was conducted on September 30 on a transect from the Boat Cove to the CVA. However, possibly due to the low survivability of FC bacteria, and considering the time that transpired between the high FC events and the time the samples were taken, no relationship was found between FCs in Boat Cove Brook and those found at the CVA. See map below.

Weather, along with the possible early arrival of sea gulls, was also looked at as a possible cause for the high counts. On September 20, a flock of approximately 600 gulls was observed in mid reservoir by Enfield Channel. There was no determination on when this particular flock arrived at Quabbin.

However, if they had been on the water prior to September 18, it is possible that wind driven currents and reservoir dynamics carried any FCs introduced into the water column by the birds down to the CVA intake.

Initially, weather data was obtained from the MA Department of Environmental Protection (DEP) Weather Station at the Quabbin Observation Tower to asses wind and precipitation conditions for the 49 hours prior to the September 18 episode. Wind speed and direction are plotted in Figure 1, which clearly shows that the wind was generally from the North at speeds averaging over 10 mph in the 24 hours previous to the event. The resulting surface current would thus have been to the south, forcing water below the surface to flow north in order to maintain a constant elevation. This means that surface water near the CVA intake was pushed down, thus carrying any bacteria down with it and into the intake. This phenomenon is observed when the water temperature at the CVA and at the surface, along with wind speed, are plotted vs. time and date (Figure 2). Figure 2 clearly shows that as the wind speed, and thus the extent of mixing, increased, water temperature at the CVA started increasing from approximately 15 ºC to almost 24 ºC, which is almost 2 ºC warmer than surface temperature (22 ºC) as measured on September 15. Figure 3, a plot of water temperature and precipitation vs. date and time, helps explain how CVA temperature surpassed surface temperature. During the 12 hours prior to the sample collection, over 3.5” of rain fell on the reservoir. The rain added over 2 billion gallons of warm rain water, which was forced down to the CVA by the wind. Any fecal matter introduced into the water column, whether by seagulls or other sources, which normally settles out, was instead rushed south by the wind and pushed onto the CVA. Figure 4, a plot of water temperature and fecal coliform counts, shows that the samples from September 18 and 29 were collected when surface water was forced down to the CVA.

Figure 1: Wind Speed and Direction (9/16/04 7:00 AM - 9/18/04 7:00 AM)

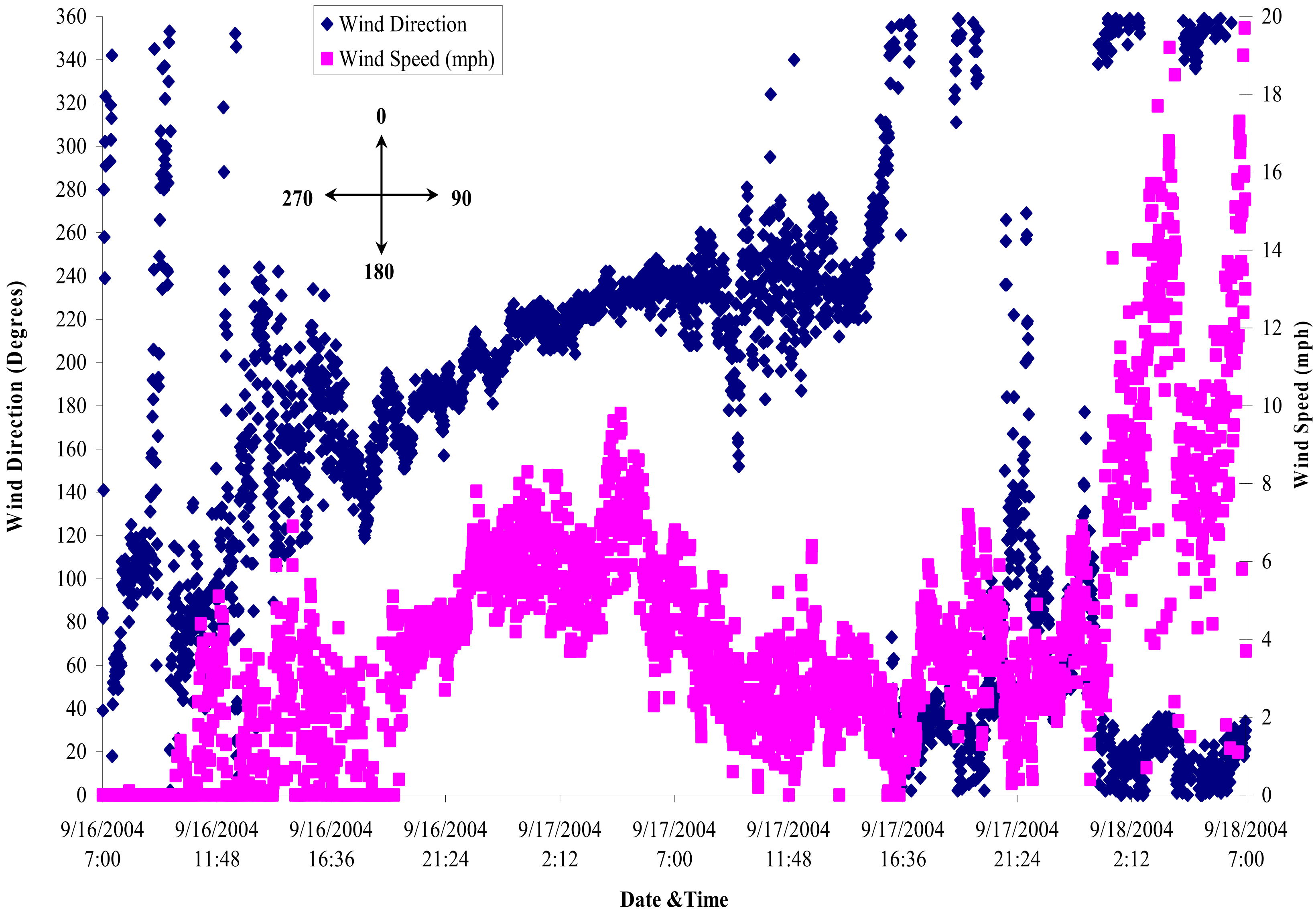


Figure 2: Water Temperature & Wind Speed vs. Date & Time (9/12 - 9/24 2004)

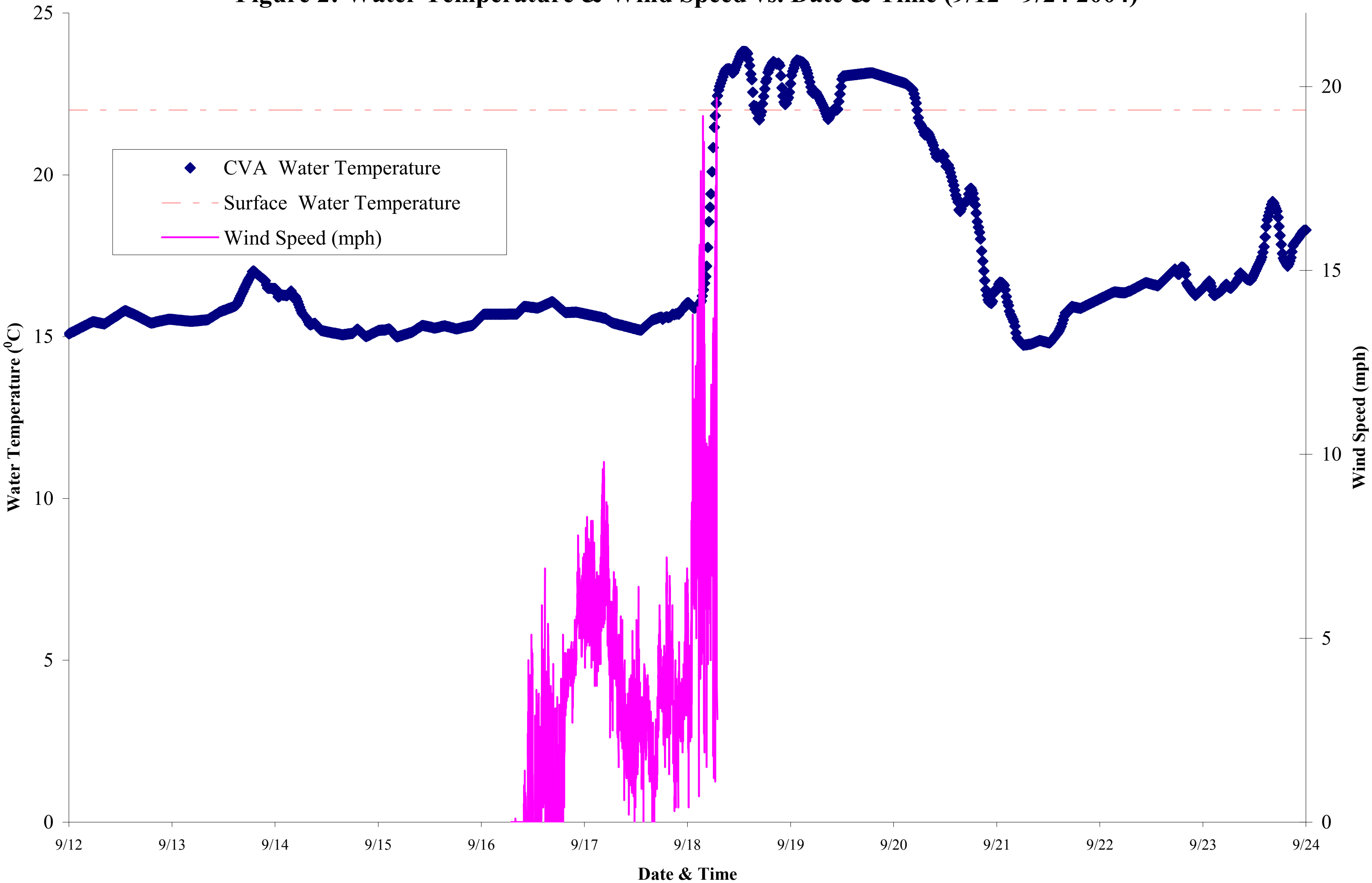


Figure 3: Water Temperature & Precipitation vs. Date & Time (September 2004)

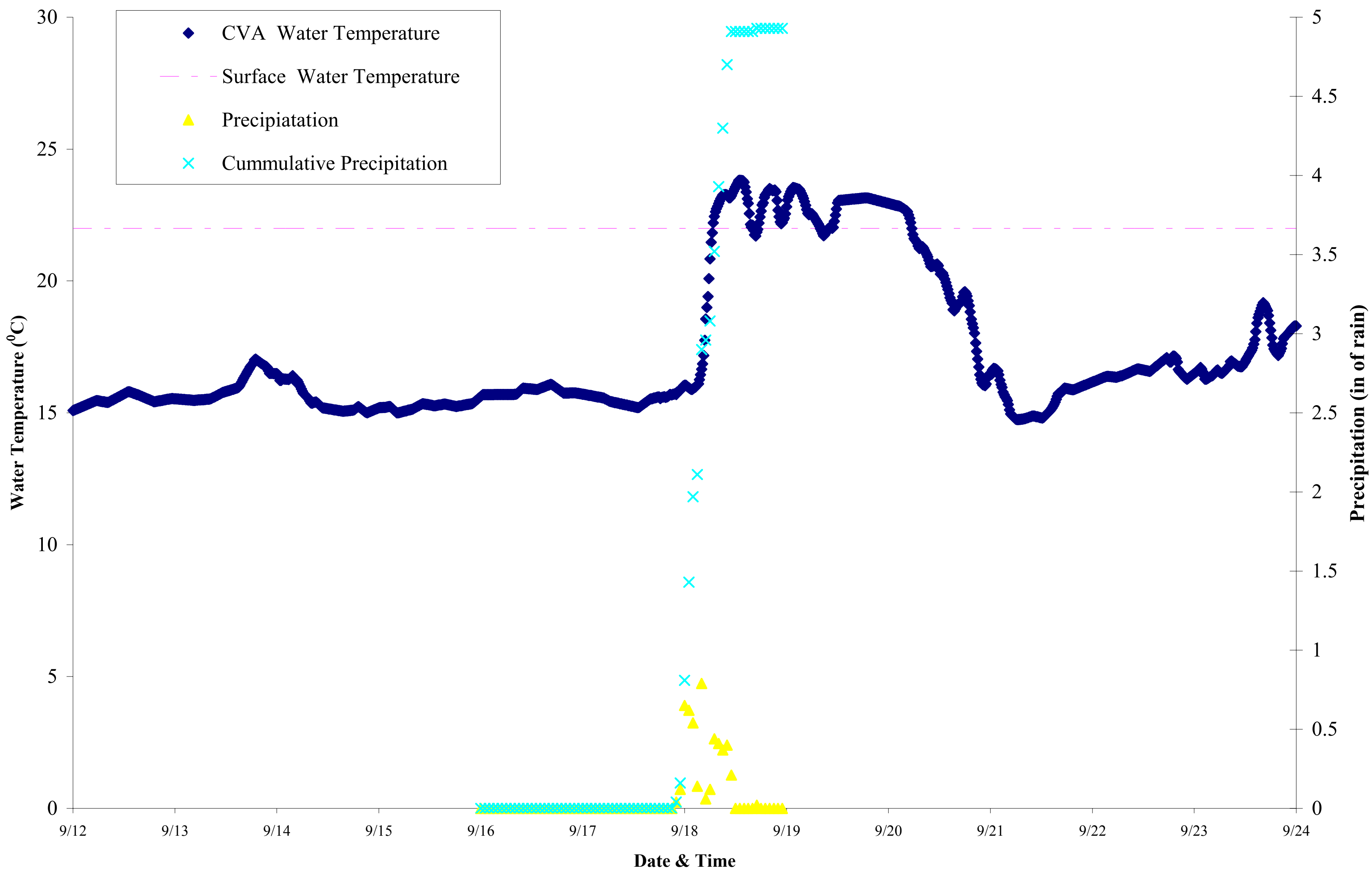
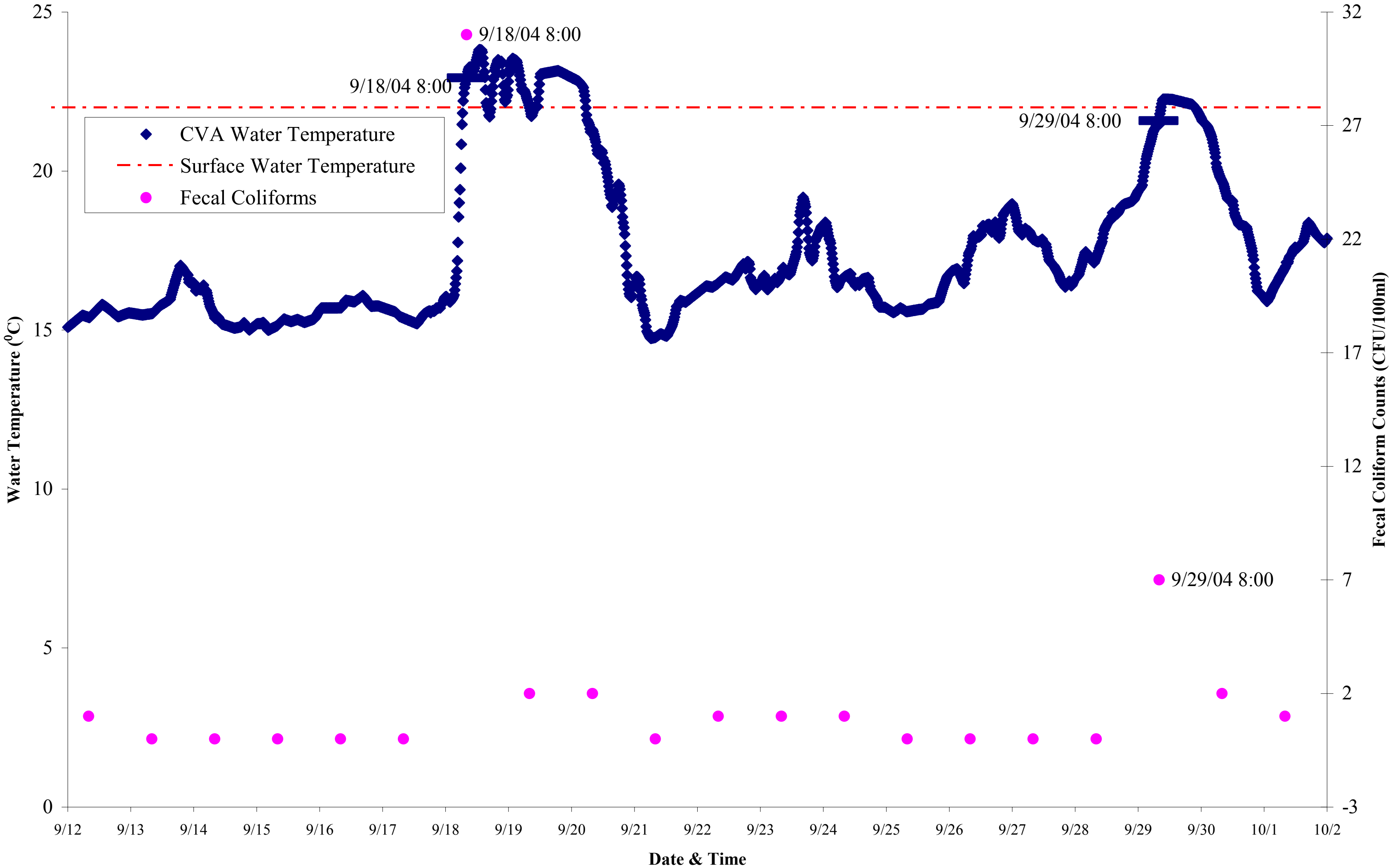


Figure 4: Water Temperature & Fecal Coliforms vs. Date & Time (912 - 10/2 2004)



Conclusion

High winds from the north and large amounts of precipitation can have a direct and fast effect on the CVA. The wind will tend to push surface water from north to south, forcing surface water down to the CVA as it flows back to the north to maintain constant elevation. As a result, anything on the surface, whether bacterial or chemical, ends up being pushed down and into the CVA intake. Further data, particularly weather data, are needed to verify the results of this analysis. A weather station, coupled with CVA on line data and lab results, will be indispensable to continue to monitor, and hopefully model, the effects of weather on the CVA.

The Commonwealth of Massachusetts
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Division of Water Supply Protection
Quabbin Section
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October 29, 2004 EQ Reference Number: EQ.WR04.004.lcg

Stephen Hughes, Acting Director
Massachusetts Department of Public Health, Division of Community Sanitation
305 South Street, 1st Floor
Jamaica Plain, MA 02130-3597

Re: DCR/DWSP 2004 Annual Report for Comet Pond Beach, Hubbardston, Massachusetts

Dear Mr. Hughes:

In compliance with M.G.L. C. 111, § 5S and regulations cited as 105 CMR 445.000: Minimum Standards for Bathing Beaches (State Sanitary Code, Chapter V11), this letter constitutes reporting of all testing, monitoring, and analysis of bathing water conducted by the Division of Conservation and Recreation/Division of Water Supply Protection(DCR/DWSP) at the Comet Pond Beach (a.k.a. Asnacomet Pond), a freshwater beach located in Hubbardston, Massachusetts during the 2004 bathing season. Currently, Comet Pond Beach is owned by the Commonwealth and operated by the DCR/DWSP. Water samples are collected by DCR staff. Water analysis is conducted by MWRA staff at the Quabbin laboratory. Based on the Division's water quality monitoring results, the bathing water quality of Comet Pond Beach during the 2004 summer season was in regulatory compliance with the standards established in 105 CMR 445.030 (**Table 1**).

In preparation of the beach opening scheduled for July 1, 2004, a DWSP Environmental Engineer and Registered Sanitarian conducted visual inspections of the beach and immediate surroundings (**Appendix A**) on June 24, 2004. Following the beach opening, Division staff made a follow-up survey on July 2, 2004, and then took weekly water samples from the beach area according to DPH prescribed methods. All water samples were analyzed according to Standard Methods (19th edition) at the DEP certified Quabbin laboratory. MWRA now operates the Quabbin Laboratory and conducts the analyses (**Appendix B**).

Comet Pond beach was officially opened on July 1, 2004. During the season, an estimated count of over 881 visitors came to the beach. The maximum number of visitors on one day during the summer was 200 people. The average number of visitors to the beach was 85 visitors per day. There were no beach closings during the 2004 summer season because of water quality results (**Appendix C**).

If you have further questions, please do not hesitate to contact Bob Bishop at (413) 323-6921 x301.

Very truly yours,

William E. Pula, P.E., Superintendent
Quabbin Section

(WEP/LCG)

Attachments:
- Table 1: Select Water Quality Data Parameters for Comet Pond Beach, June-August 2004
- Appendix A: Preseason Swimming Beach Survey for Comet Pond - June 24, 2004
- Appendix B: EQ Field Data Summary Table, Comet Pond Beach, June-August 2004
- Appendix C: Comet Pond Beach, Lifeguard Daily Report 2004

cc: Peter Church Acting Director – Division of Water Supply Protection, DCR
John Gregoire, MWRA
Eva Tor, MA DEP, Western Region

Table 1
Select Water Quality Parameters

Comet Pond Beach Data - 2004				
Sample Date		***E. Coli*** **(#colonies/100mL)**	**Geometric Mean of last 5 *E.Coli* samples**	**Fecal Coliform Bacteria (#cfu/100mL)**
7/7/2004	Left	0	NA	0
7/7/2004	Center	1	NA	2
7/7/2004	Right	1	NA	0
7/15/2004	Left	0	NA	0
7/15/2005	Center	0	NA	1
7/15/2004	Right	0	NA	3
7/21/2004	Left	4	NA	10
7/21/2004	Center	4	NA	4
7/21/2004	Right	18	3.10	12
7/28/2004	Left	0	3.10	4
7/28/2004	Center	0	3.10	3
7/28/2004	Right	0	3.10	1
8/4/2004	Left	3	3.87	6
8/4/2004	Center	0	3.87	3
8/4/2004	Right	1	3.87	1
8/11/2004	Left	1	2.93	0
8/11/2004	Center	0	2.93	1
8/11/2004	Right	0	2.93	1
8/18/2004	Left	1	2.22	1
8/18/2004	Center	2	1.43	0
8/18/2004	Right	0	1.43	2
8/25/2004	Left	0	1.43	0
8/25/2004	Center	0	1.43	0
8/25/2004	Right	0	1.43	0

Appendix A

MDC/DWM
2004 Comet Pond Beach Survey
Ware River Watershed

Prepared by:
Matt Hopkinson, PE, EEIII
Metropolitan District Commission/ Division of Watershed Management

June, 2004

In preparation for the beach opening for the 2004 swim season, the MDC Division of Watershed Management conducted a special sanitary survey of the Comet Pond Beach area. Field visits were conducted on June 24 and July 2. June 25 was the date of a thorough beach survey and bottom survey. Water quality samples were collected on July 2. The pond outlet was observed during routine sampling on June 29.

The figure at the end of the report shows the contributing drainage area for Comet *(or Asnacomet)* Pond. The only tributary of any size drains a wooded undeveloped area to the northeast of the pond. This tributary is limited in size to about three feet wide. The diagonally hatched areas are MDC land holdings and are mostly wooded. Sample site 116 is located at the pond outlet and Sample Site 116A is located at the public beach.

Beach Survey

Under the guidance of Bob Bishop, Registered Sanitarian, Matt Hopkinson Registered Civil Engineer conducted a visual inspection of the beach and the immediate surroundings on June 24. The beach was currently being prepared for opening day by MDC personnel. Pete Warakomski, DCR staff reported that he had picked up litter and some broken bottles. The sand beach had not yet been raked for the new season. Some minor amounts of trash and broken glass were observed in the woods.

On June 25, the bottom was inspected via canoe. Two fishing lures and a hairtie were seen on the bottom.

At 11:00 AM, the beach was empty. By 12:30, there were several adults and kids swimming at the beach, even though it was not scheduled to open for another week.

Once again, a portable toilet was delivered prior to the swim season to accommodate fishing and other activities that have led to observed sanitation problems. On this visit, the can was in place and was reasonably clean. Mr. Warakomski reported that the maintenance person for the toilet had left a pile of trash beside the toilet that had been thrown into the toilet. A second handicap accessible unit was was in place on the July 2 visit.

Shoreline vegetation was hacked down in several locations near the beach to accommodate fishing. This could be prevented by preventing parking at the gate.

Wildlife

There were no signs of problem wildlife. There was no evidence of geese or beavers at the beach. At the pond outlet, as observed on June 29, the beaver outlet device was in disrepair. It did not appear to have been maintained for at least a year. No beaver activities were observed along the shorelines.

Agriculture and development

Agriculture remains the same as last year, with one cattle farm at the north end of the pond. The cows do not have access to the water. Residential development remains sparse, though primitive camps continue to get incrementally larger each year.

Water Conditions

Mr. Bishop confirmed the sampling program would remain the same as last year's, with three samples collected in three feet of water at right, left and center as viewed from the beach. Due to budget considerations, Wednesdays were designated as the weekly sampling day. On Friday, July 2, Matt Hopkinson collected the samples and conducted the first beach survey. The weather was calm and clear. There were no visitors at the time of the survey. Mr. Hopkinson viewed the bottom on foot using chest waders. Ther was no wrack line. No trash was observed.

Conclusions and Recommendations

Issues brought up in previous years seem to have been resolved. The beach appears to be safe and healthy.

Asnacomet Subdistrict

- MDC Land
- Other Conservation Land
- Commercial/Industrial
- Residential
- Agriculture
- Developed Open Land
- Undeveloped Open Land
- Forest
- Wetland
- Open Water
- Areas outside of Subdistrict
- Sanitary Subdistrict
- Stream Compartment
- Town Boundary
- MDC Boundary
- Parcel Boundary
- Transmission Line
- Railroad Track
- Underground Phone Cable
- Aqueduct
- Major Road
- Road
- 4WD Trail
- Trail
- Contours
- UTM Grid
- Stream
- DEP Stream Features
- Intermittent Stream
- Boat Fishing Limit
- Fishing Area
- MDC Gate
- Solid Waste Site
- Underground Storage Tank Site
- Water Quality Sample Site

Landuse:
MDC/MWRA Landuse Program
(interpreted from 1:12000 Spring 1992-93 photos; Landuse classification are interpretations of aerial photos, and are not necessarily in conformance with local zoning designations or with actual activities taking place at specific sites)

Wetland & Surface Water:
DEP Wetland Conservancy Program
(interpreted from 1:12,000 Spring 1992-93 photos; latest revision 4/96)

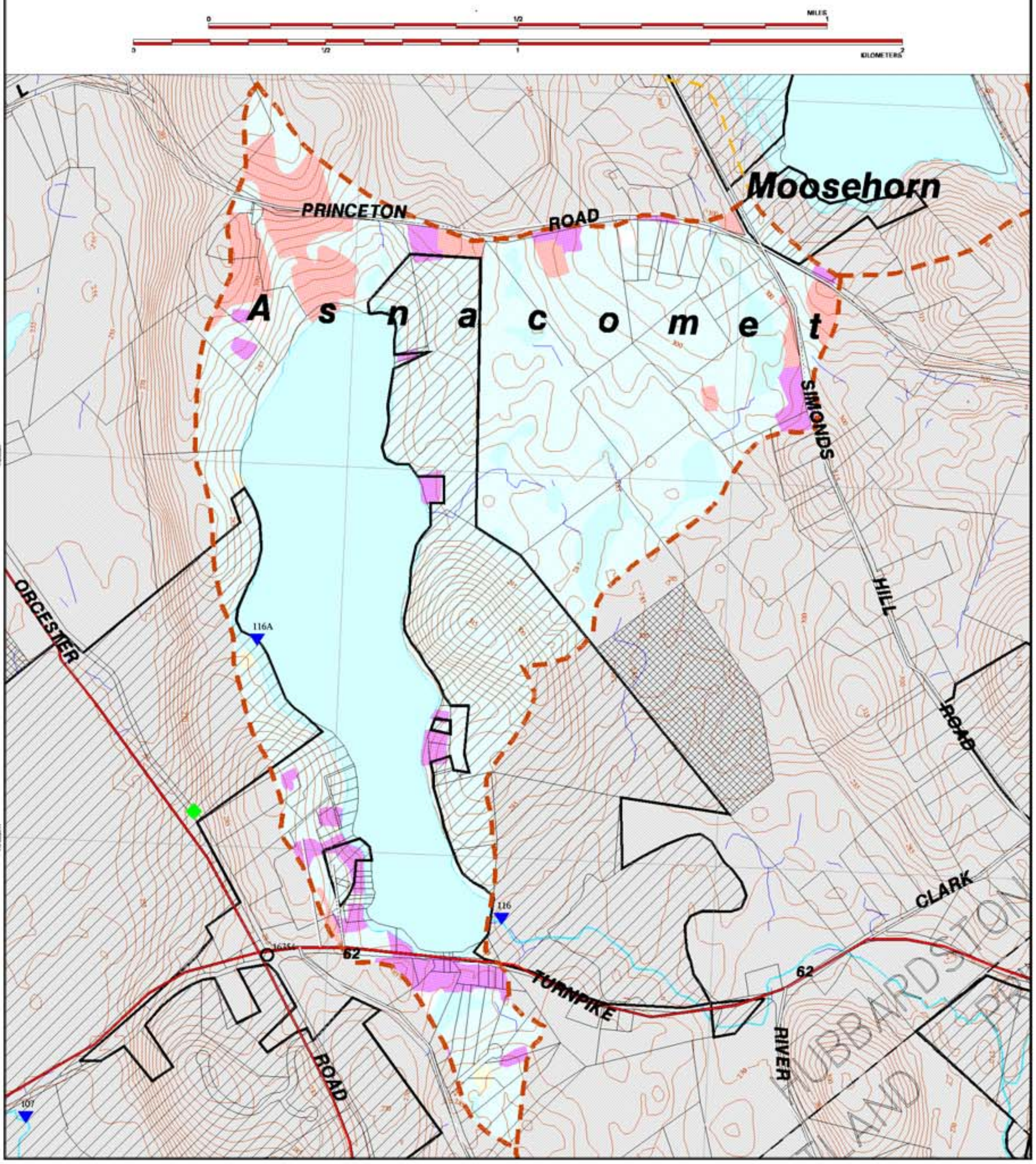
Streams:
DEP Wetland Conservancy Program
(interpreted from 1:12,000 Spring 1992-93 photos; latest revision 4/96)
USGS-NWD 1:25,000 DLGs
(Enhanced by MassGIS; latest revision 12/97)
USGS-NWD 1:25,000 Separates
(Scanned and enhanced by MassGIS; latest revision 12/97)

Roads:
USGS-NWD 1:100,000 DLGs
(Enhanced by Mass Highway Dept.; latest revision 12/98)

Contours:
MassGIS 1:5,000 DOQ Project
(Generated from DTM and accurate to 1.5 meters; latest revision 12/95)

Community Boundaries:
Compiled on 1:25,000 Quads
(Automated by MassGIS & MDC; latest revision 3/91)

Watershed Boundaries:
Compiled by USGS-WRD at 1:24,000
(Automated by MassGIS & MDC; latest revision 3/90)



Appendix B
EQ Field Data Summary Table, Comet Pond Beach, June-August 2004

Date	Staff	ID	Time Collected	Time Delivered	Type of Water (salt/fresh)	Water Temp (°C)	Water Clarity* (clear/ not clear)	Swimmer Density (in water/total number)	Conditions within portable Toilets	Conditions of grounds	Current Weather Conditions	Air Temp (°C)	Amount of Last Rainfall (inches)	Number of days from end of last rainfall to collection day	Comments	Fecal Coliform Bacteria (Left) # cfu/100 mL	Fecal Coliform Bacteria (Middle) #cfu/100 mL	Fecal Coliform Bacteria (Right) #cfu/100 mL	E. Coli (left)	E. Coli (middle)	E. Coli (right)
7/7/2004	MH	04052970-72	9:30am	10:45 am	fresh	23	clear	0	ok. Handicap unit in place.	clean, not raked	sunny, clear	21	na	2		0	2	0	0	1	1
7/15/2004	MH	04052973-75	na	10:28 am	fresh	21	clear	0	clean and well maintained	litter-free, only partly raked	clear	17	light	0	Outer "do not cross" rope and signs broken, needs repair	0	1	3	0	0	0
7/21/2004	MH	04052976-78	9:00am	10:10 am	fresh	na	clear	0	clean	fully raked, clean	sunny, hazy, calm	19	na	2	Several sets of footprints after raked, including one set of dog tracks	10	4	12	4	4	18
7/28/2004	PD	04052979-81	9:15am	10:20 AM	fresh	22	clear	0	ok	not raked and some litter	light rain falling	14	light	0	Not a nice beach day! Previous day was also cool and cloudy.	4	3	1	0	0	0
8/4/2004	MH	04046608-610	10:15am	11:00 am	fresh	25	na	5/17	ok		nice	22	2.1	1	Arrived after opening at 10am,	6	3	1	3	0	1

Date	Staff	ID	Time Collected	Time Delivered	Type of Water (salt/fresh)	Water Temp (°C)	Water Clarity* (clear/not clear)	Swimmer Density (in water/total number)	Conditions within portable Toilets	Conditions of grounds	Current Weather Conditions	Air Temp (°C)	Amount of Last Rainfall (inches)	Number of days from end of last rainfall to collection day	Comments	Fecal Coliform Bacteria (Left) # cfu/100 mL	Fecal Coliform Bacteria (Middle) #cfu/100 mL	Fecal Coliform Bacteria (Right) #cfu/100 mL	E. Coli (left)	E. Coli (middle)	E. Coli (right)
															already a big crowd.						
8/11/2004	MH	04049400-03	9:15am	11:05 am	fresh	23	clear	0	good	not raked and some litter in woods	overcast	21	0.01	0	Looks good	0	1	1	1	0	0
8/18/2004	MH	4048710-12	na	10:10 am	fresh	22	clear	1	crud on back of toilet seat in handicap unit still there after 1 week	ok	overcast	16	0.01	1	1 visitor fishing near beach (right)	1	0	2	1	2	0
8/25/2004	MH	4050327-29	9:37am	10:43 am	fresh	22	clear	0	clean	good	morning fog	17	na	3	beach closes at end of this week (8/27/04)	0	0	0	0	0	0

Appendix C
Comet Pond Beach, Lifeguard Daily Data Sheet, Summer 2004

Day	*Date*	*Name*	*Police Check (Time)*	*Weather Conditions*	*Number of Visitors*	*Number of Cars*	*Number of Incidents Reported*	*Incident Description*	*Rake Beach*	*Clean Sani-Cans*	*Police Trash in adjacent wooded area*	*Rain Gauge (morning*
Thursday	7/1/2004	Emily	na	sunny, hot, & humid - severe thunderstorms later in the evening	70	30	0	NA	yes	yes	yes	na - stolen
Friday	7/2/2004	Emily	3:00pm	sunny, hot & t-storm mid-day	60	20	0	NA	yes	yes	yes	na - stolen
Saturday	7/3/2004	Emily	1:00pm	hot & sunny	70	30	0	NA	yes	yes	yes	na - stolen
Sunday	7/4/2004	Brendan	na	partly cloudy	50	20	0	NA	yes	yes	yes	na - stolen
Monday	7/5/2004	Brendan	na	rainy	5	2	1	A woman and kids were fishing when lifeguards arrived. Brendan told them they couldn't fish explaining about fishhooks and she made a big deal about it.	no	yes	yes	na - stolen
	7/6/2004	na										
	7/7/2004	na										
	7/8/2004	na										
Saturday	7/9/2004	Emily	na	mostly cloudy, cool	30	10	0	NA	yes	yes	yes	na - stolen
Sunday	7/10/2004	Emily	10:30, 2:00	hot, sunny	90	40	0	NA	yes	yes	yes	na - stolen
Monday	7/11/2004	Emily	na	partly cloudy	50	15	0	NA	yes	yes	yes	na -

Day	***Date***	***Name***	***Police Check (Time)***	***Weather Conditions***	***Number of Visitors***	***Number of Cars***	***Number of Incidents Reported***	***Incident Description***	***Rake Beach***	***Clean Sani-Cans***	***Police Trash in adjacent wooded area***	***Rain Gauge (morning***
												stolen
Tuesday	7/13/2004	Carolyn	11:35	cloudy	0	0	0	NA	yes	yes	yes	na - stolen
Wednesday	7/14/2004	Carolyn	na	cloudy, rainy	2	1	0	NA	no	no	no	na - stolen
Thursday	7/15/2004	na										
Friday	7/16/2004	Emily	na	hot, sunny	90	45	0	NA	yes	yes	yes	na - stolen
Saturday	7/17/2004	Emily	3:00	hot, sunny	115	45	0	NA	yes	yes	yes	na - stolen
Sunday	7/18/2004	Emily	11:00	partly sunny, hot, humid	100	40	0	NA	yes	yes	yes	na - stolen
Monday	7/19/2004	Brendan	na	rainy	4	2	0	NA	yes	yes	yes	na - stolen
Tuesday	7/20/2004	Brendan	11:00	partly cloudy, humid	200	80	0	NA	yes	yes	yes	na - stolen
Wednesday	7/21/2004	Emily	11:00	hot, humid, sunny	200	100	0	NA	yes	yes	yes	na - stolen
		Statistics:										
Sum		Count			881	378	0					
Minimum		Minimum			0	0						
Maximum		Maximum			200	100						
Average		Average			85	37						
Median		Median			90	40						

MEMO

TO: Bob Bishop and Scott Campbell
FROM: Dave Worden
DATE: March 8, 2005
RE: Results of 2004 Quarterly Nutrient Sampling at Quabbin Reservoir

The nutrient database for Quabbin Reservoir established in the 1998-99 year of monthly sampling and subsequent quarterly sampling through 2003 is used as a basis for interpreting data generated in 2004 (see Table 2004 and complete quarterly database in accompanying Excel file). Results of quarterly nutrient sampling in 2004 document concentrations and intensities that register almost entirely within historical ranges.

The only parameter with values significantly higher than historical ranges is total phosphorus with two values measured in May appearing elevated. Specifically, these values were reported in the epilimnion at Winsor Dam/Station 202 and in the hypolimnion at Mt. Pomeroy/Station 206 (see Table 2004 and quarterly database). However, an extensive record of duplicate sample analysis demonstrates that total phosphorus is the nutrient most difficult to measure with consistent precision. The concentration of this parameter in Quabbin samples is often at or below the laboratory detection limit of 5 ug/L and this factor introduces a degree of unreliability in the analysis. The instances of elevated values reported in 2004 are likely an artifact of this difficultly and do not signify essential changes in water quality.

The patterns of nutrient distribution in 2004 quarterly samples were comparable to those documented previously in the 2000 report on Quabbin nutrient and plankton dynamics. These patterns consist of the following: (1) prominent seasonal and vertical variations due to demand by phytoplankton in the trophogenic zone (low concentrations in the epilimnion and metalimnion) and decomposition of sedimenting organic matter in the tropholytic zone (higher concentrations accumulating in the hypolimnion), (2) a lateral gradient in silica concentrations correlated to hydraulic residence time and mediated by diatom population dynamics, (3) and slightly higher concentrations and intensities at the Den Hill monitoring station due to the loading effects of the East Branch Swift River. Future nutrient sampling at Quabbin Reservoir is planned to continue on the established quarterly schedule. Please contact me with any questions or comments.

Results of Quarterly Nutrient Sampling:
UV254 (A/cm)

I.D.	Sampling Station	Sampling Date				Median	Average	Min.	Max.
		05/25/04	08/18/04	11/09/04	12/15/04				
MD28	WD/202 (E)	0.024	0.022	0.022	0.021	0.022	0.022	0.021	0.024
MD29	WD/202 (M)	0.023	0.027	0.022	0.023	0.023	0.024	0.022	0.027
MD30	WD/202 (H)	0.023	0.022	0.022	0.022	0.022	0.022	0.022	0.023
MD37	MP/206 (E)	0.031	0.024	0.022	0.022	0.023	0.025	0.022	0.031
MD38	MP/206 (M)	0.026	0.029	0.022	0.023	0.025	0.025	0.022	0.029
MD39	MP/206 (H)	0.024	0.024	0.022	0.023	0.024	0.023	0.022	0.024
MD40	Den Hill (E)	0.065	0.032	0.043	0.062	0.053	0.051	0.032	0.065
MD41	Den Hill (M)	0.060	0.036	0.044	na	0.044	0.047	0.036	0.060
MD42	Den Hill (H)	0.071	0.070	0.045	na	0.070	0.062	0.045	0.071

Results of Quarterly Nutrient Sampling:
Total Phosphorus (mg/L; MDL = 0.005)

I.D.	Sampling Station	Sampling Date				Median	Average	Min.	Max.
		05/25/04	08/18/04	11/09/04	12/15/04				
MD28	WD/202 (E)	0.020	0.008	0.007	0.005	0.008	0.010	0.005	0.020
MD29	WD/202 (M)	0.007	0.012	0.009	**	0.009	0.010	0.007	0.012
MD30	WD/202 (H)	0.006	0.010	0.008	0.007	0.008	0.008	0.006	0.010
MD37	MP/206 (E)	0.006	0.008	*0.005*	0.006	0.006	0.006	*0.005*	0.008
MD38	MP/206 (M)	0.005	0.012	0.007	*0.005*	0.006	0.007	*0.005*	0.012
MD39	MP/206 (H)	0.019	0.012	*0.005*	0.006	0.009	0.011	*0.005*	0.019
MD40	Den Hill (E)	0.007	0.009	*0.005*	0.008	0.007	0.007	*0.005*	0.009
MD41	Den Hill (M)	0.010	0.009	*0.005*	na	0.009	0.008	*0.005*	0.010
MD42	Den Hill (H)	0.008	0.013	*0.005*	na	0.008	0.009	*0.005*	0.013

Note: values show in italix are <MDL

**Reported value of 0.0232 mg/L unlikely given values above and below during mixis; omitted from database

Results of Quarterly Nutrient Sampling:
Ammonia (mg/L; MDL = 0.005)

I.D.	Sampling Station	Sampling Date				Median	Average	Min.	Max.
		05/25/04	08/18/04	11/09/04	12/15/04				
MD28	WD/202 (E)	0.005	*0.005*	0.005	*0.005*	0.005	0.005	*0.005*	0.005
MD29	WD/202 (M)	*0.005*	*0.005*	0.005	0.007	0.005	0.005	*0.005*	0.007
MD30	WD/202 (H)	*0.005*	0.022	0.026	*0.005*	0.014	0.015	*0.005*	0.026
MD37	MP/206 (E)	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
MD38	MP/206 (M)	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
MD39	MP/206 (H)	0.008	0.019	*0.005*	*0.005*	0.006	0.009	*0.005*	0.019
MD40	Den Hill (E)	*0.005*	*0.005*	0.013	0.012	0.009	0.009	*0.005*	0.013
MD41	Den Hill (M)	*0.005*	*0.005*	0.012	na	*0.005*	0.007	*0.005*	0.012
MD42	Den Hill (H)	0.021	0.012	0.012	na	0.012	0.015	0.012	0.021

Note: values show in italix are <MDL

Results of Quarterly Nutrient Sampling:
Nitrate (mg/L; MDL =
0.005)

I.D.	Sampling Station	Sampling Date				Median	Average	Min.	Max.
		05/25/04	08/18/04	11/09/04	12/15/04				
MD28	WD/202 (E)	0.015	*0.005*	0.007	0.015	0.011	0.010	*0.005*	0.015
MD29	WD/202 (M)	0.012	*0.005*	0.006	0.016	0.009	0.010	*0.005*	0.016
MD30	WD/202 (H)	0.015	0.031	0.034	0.014	0.023	0.024	0.014	0.034
MD37	MP/206 (E)	0.005	*0.005*	0.006	0.012	0.006	0.007	*0.005*	0.012
MD38	MP/206 (M)	0.005	*0.005*	0.005	0.013	0.005	0.007	*0.005*	0.013
MD39	MP/206 (H)	0.013	0.095	0.006	0.011	0.012	0.031	0.006	0.095
MD40	Den Hill (E)	0.008	*0.005*	0.008	0.021	0.008	0.010	*0.005*	0.021
MD41	Den Hill (M)	0.012	*0.005*	0.007	na	0.007	0.008	*0.005*	0.012
MD42	Den Hill (H)	0.048	0.078	0.009	na	0.048	0.045	0.009	0.078

Note: values show in italix are <MDL

Results of Quarterly Nutrient Sampling:
TKN (mg/L; MDL = 0.05)

I.D.	Sampling Station	Sampling Date				Median	Average	Min.	Max.
		05/25/04	08/18/04	11/09/04	12/15/04				
MD28	WD/202 (E)	0.160	0.157	0.101	0.129	0.143	0.137	0.101	0.160
MD29	WD/202 (M)	0.190	0.168	0.149	0.127	0.159	0.159	0.127	0.190
MD30	WD/202 (H)	0.091	0.135	0.156	0.098	0.117	0.120	0.091	0.156
MD37	MP/206 (E)	0.184	0.125	0.165	0.148	0.157	0.156	0.125	0.184
MD38	MP/206 (M)	0.160	0.142	0.140	0.142	0.142	0.146	0.140	0.160
MD39	MP/206 (H)	0.160	0.113	0.149	0.154	0.152	0.144	0.113	0.160
MD40	Den Hill (E)	0.179	0.133	0.200	0.212	0.190	0.181	0.133	0.212
MD41	Den Hill (M)	0.184	0.154	0.206	na	0.184	0.181	0.154	0.206
MD42	Den Hill (H)	0.148	0.150	0.191	na	0.150	0.163	0.148	0.191

Results of Quarterly Nutrient Sampling:
Silica (mg/L)

I.D.	Sampling Station	Sampling Date				Median	Average	Min.	Max.
		05/25/04	08/18/04	11/09/04	12/15/04				
MD28	WD/202 (E)	1.82	1.43	1.59	1.52	1.56	1.59	1.43	1.82
MD29	WD/202 (M)	1.78	1.39	1.58	1.68	1.63	1.61	1.39	1.78
MD30	WD/202 (H)	1.74	1.86	2.15	1.72	1.80	1.87	1.72	2.15
MD37	MP/206 (E)	1.55	1.31	1.54	1.62	1.55	1.51	1.31	1.62
MD38	MP/206 (M)	1.48	1.28	1.52	1.56	1.50	1.46	1.28	1.56
MD39	MP/206 (H)	1.49	1.92	1.51	1.56	1.54	1.62	1.49	1.92
MD40	Den Hill (E)	2.41	1.00	1.74	2.14	1.94	1.82	1.00	2.41
MD41	Den Hill (M)	2.39	1.22	1.65	na	1.65	1.75	1.22	2.39
MD42	Den Hill (H)	3.14	3.31	1.76	na	3.14	2.74	1.76	3.31

Results of Quarterly Nutrient Sampling:
Dissolved Silica (mg/L)

I.D.	Sampling Station	Sampling Date				Median	Average	Min.	Max.
		05/25/04	08/18/04	11/09/04	12/15/04				
MD28	WD/202 (E)	1.85	0.58	1.54	1.54	1.54	1.38	0.58	1.85
MD29	WD/202 (M)	1.77	0.51	1.59	1.53	1.56	1.35	0.51	1.77
MD30	WD/202 (H)	1.78	0.40	1.97	1.6	1.69	1.44	0.40	1.97
MD37	MP/206 (E)	1.57	0.56	1.48	1.45	1.47	1.27	0.56	1.57
MD38	MP/206 (M)	1.49	0.40	1.47	1.49	1.48	1.21	0.40	1.49
MD39	MP/206 (H)	1.46	0.34	1.5	1.42	1.44	1.18	0.34	1.50
MD40	Den Hill (E)	2.46	0.46	1.66	2.07	1.87	1.66	0.46	2.46
MD41	Den Hill (M)	2.40	0.36	1.68	na	1.68	1.48	0.36	2.40
MD42	Den Hill (H)	3.20	0.54	1.68	na	1.68	1.81	0.54	3.20

Results of Quarterly Nutrient Sampling:
Alkalinity (mg/L as $CaCO_2$)

I.D.	Sampling Station	Sampling Date				Median	Average	Min.	Max.
		05/25/04	08/18/04	11/09/04	12/15/04				
MD28	WD/202 (E)	2.68	2.56	2.74	3.18	2.71	2.79	2.56	3.18
MD29	WD/202 (M)	2.74	2.74	2.78	2.70	2.74	2.74	2.70	2.78
MD30	WD/202 (H)	2.60	2.66	2.70	2.72	2.68	2.67	2.60	2.72
MD37	MP/206 (E)	2.76	2.62	2.70	2.80	2.73	2.72	2.62	2.80
MD38	MP/206 (M)	2.88	2.84	2.64	2.60	2.74	2.74	2.60	2.88
MD39	MP/206 (H)	2.72	2.78	2.80	2.64	2.75	2.74	2.64	2.80
MD40	Den Hill (E)	2.52	2.72	3.18	3.24	2.95	2.92	2.52	3.24
MD41	Den Hill (M)	2.80	3.06	3.14	na	3.06	3.00	2.80	3.14
MD42	Den Hill (H)	2.50	2.90	3.18	na	2.90	2.86	2.50	3.18

2004 Chicopee Valley Aqueduct Intake Giardia and Cryptosporidium Results, oocysts/100L

						Giardia		Crypto		
Date	Method	Filter Type	Volume Filtered (L)	Volume Examined (L)	Detection Limit, #/100 L	Total Microscopic count / Volume Examined	Calculated #/100 L	Total Microscopic count / Volume Examined	Calculated #/100 L	Lab
1/26/04	ASTM D19		378.5	189	0.53	0	0	0	0	Erie County Water Authority
2/2/04	ASTM D19		378.5	189	0.53	0	0	0	0	Erie County Water Authority
02/23/04	ASTM D19		378.5	189	0.53	0	0	0	0	Erie County Water Authority
03/15/04	ASTM D19		378.5	189	0.53	0	0	0	0	Erie County Water Authority
03/29/04	ASTM D19		378.5	189	0.53	0	0	0	0	Erie County Water Authority
04/12/04	ASTM D19		378.5	189	0.53	0	0	0	0	Erie County Water Authority
04/27/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
05/11/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
05/25/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
06/08/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
06/22/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
07/06/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
07/20/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
08/03/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
08/17/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
09/01/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
09/14/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
09/28/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
10/12/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
10/27/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
11/08/04	EPA 1623	Gelman HV	50	50	2	**2***	**4**	0	0	Analytical Service, Inc
11/22/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc
12/07/04	EPA 1623	Gelman HV	50	50	2		0	0	0	Analytical Service, Inc
12/22/04	EPA 1623	Gelman HV	50	50	2	0	0	0	0	Analytical Service, Inc

Notes: *Empty 1 Amorphou 0 One 0 >One 1 Total 2

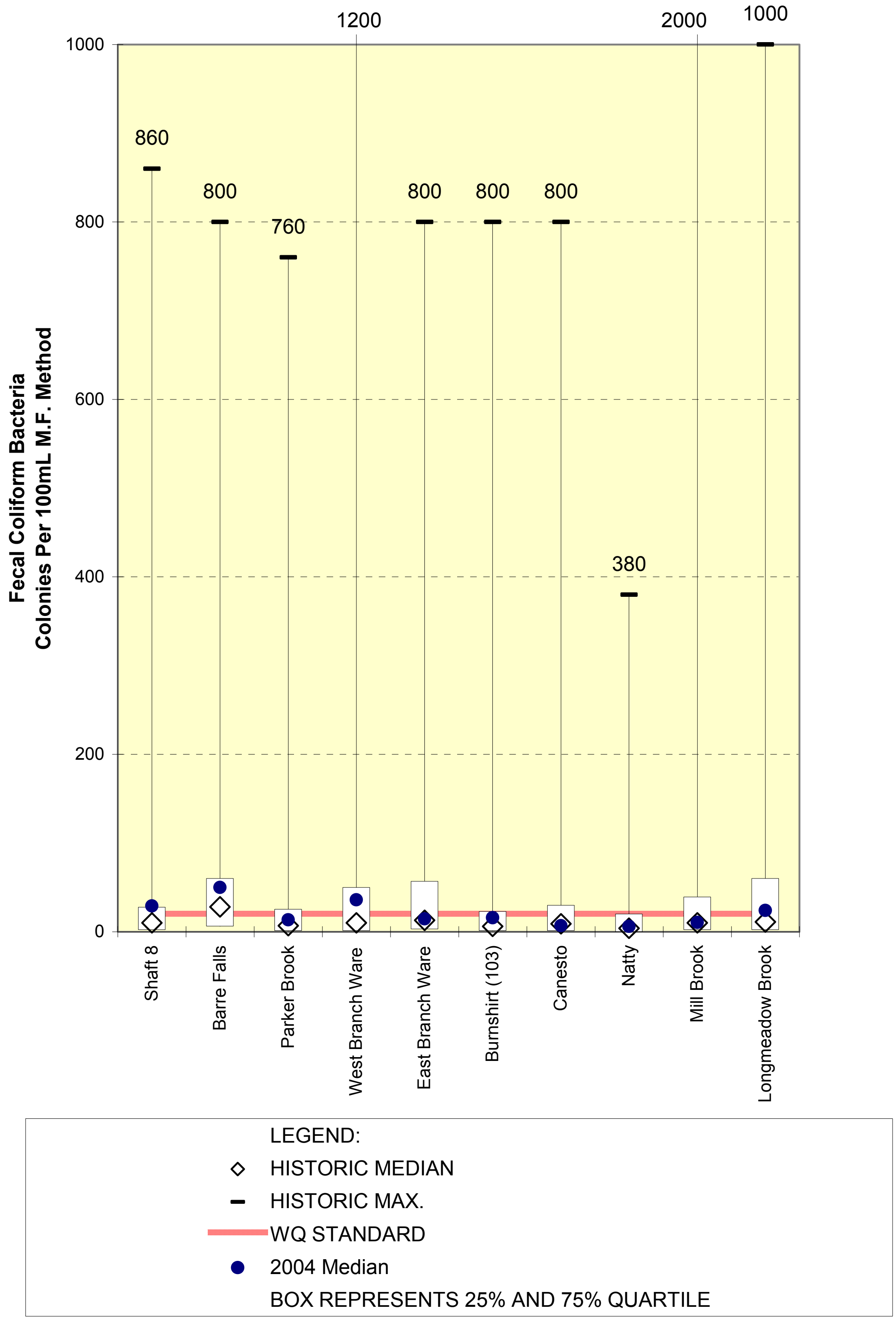
APPENDIX B

Selected Plots and Graphs:

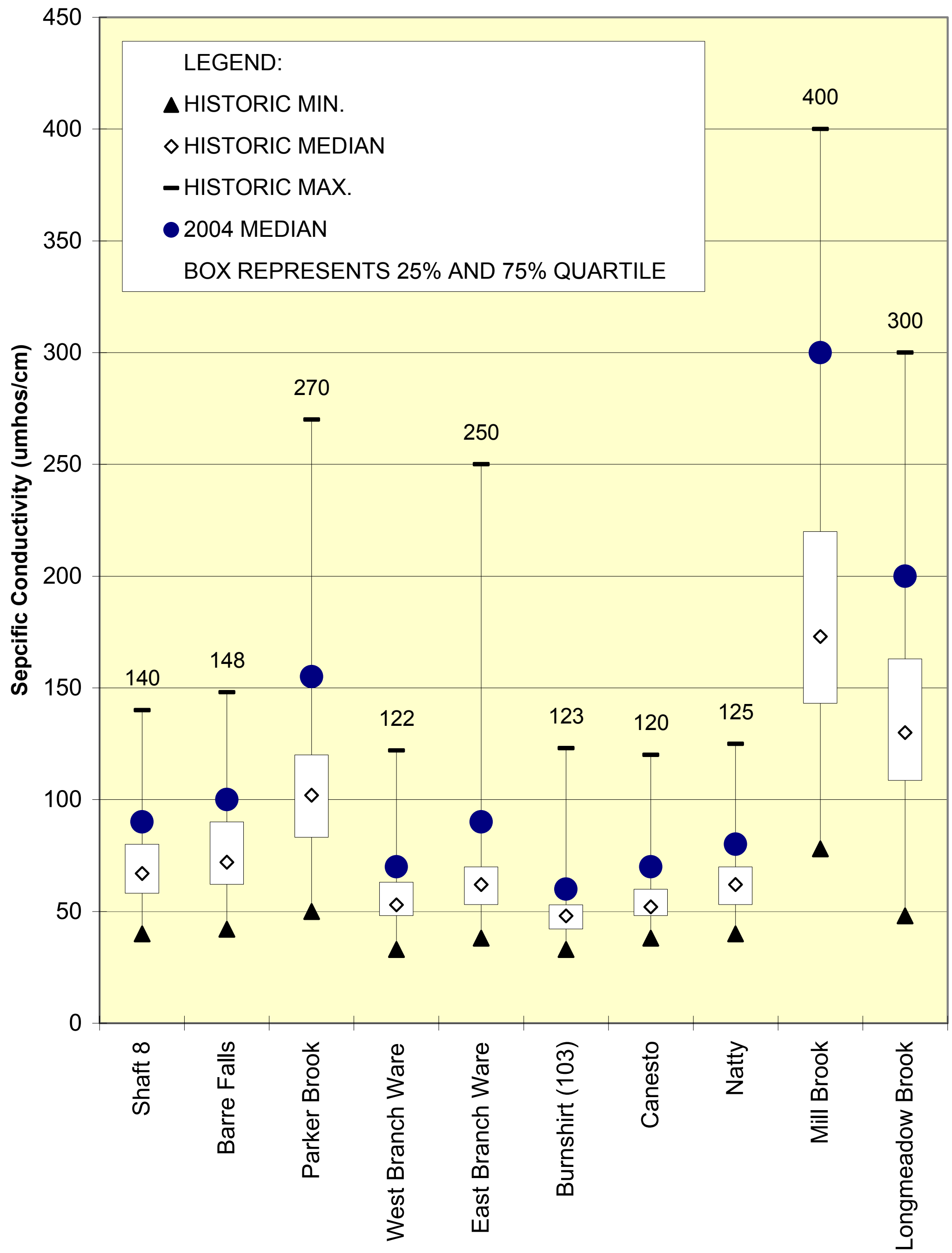
Parameter Box Plots 1990-2004

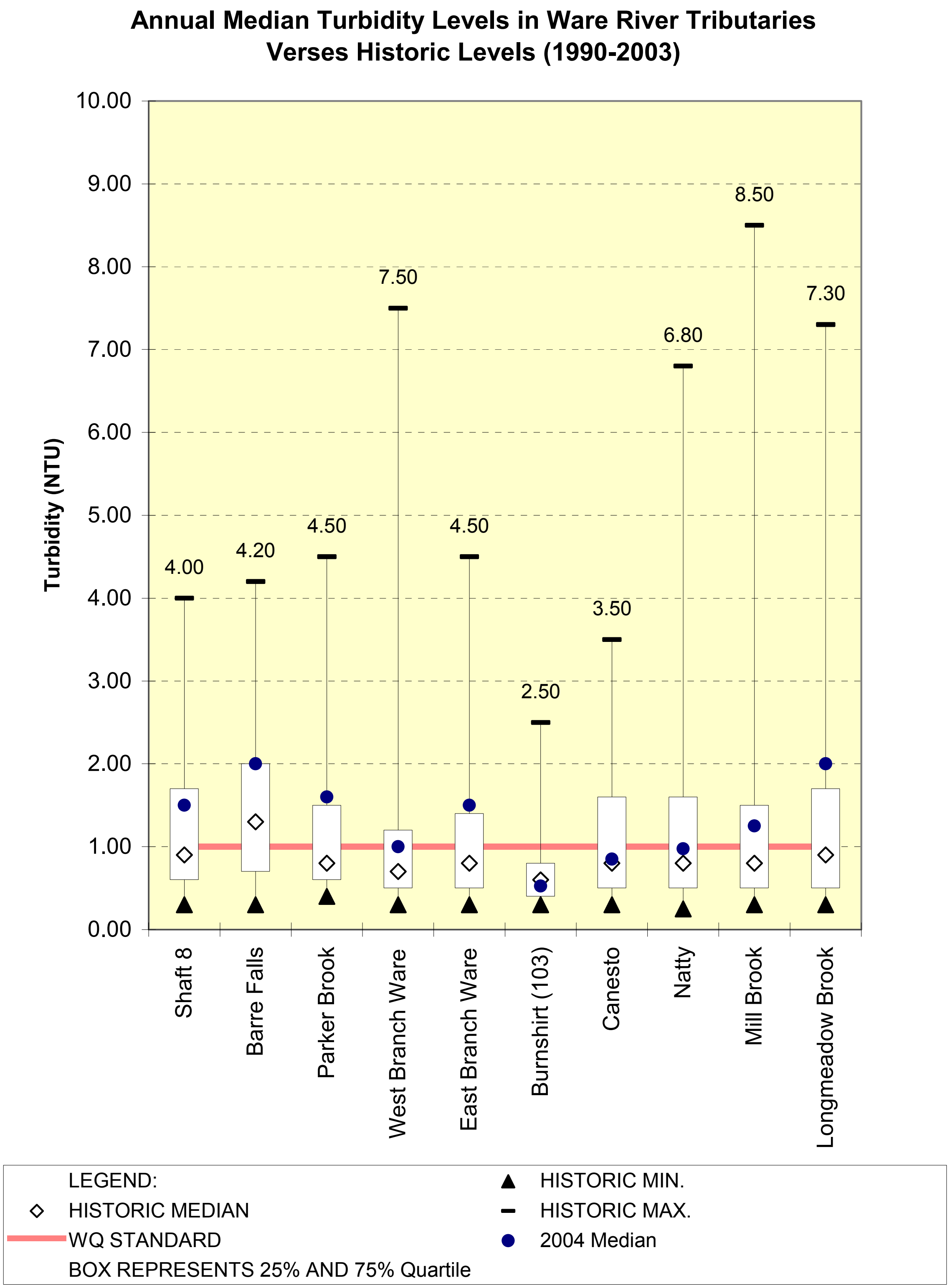
2004 Reservoir Profiles: Temperature and Dissolved Oxygen

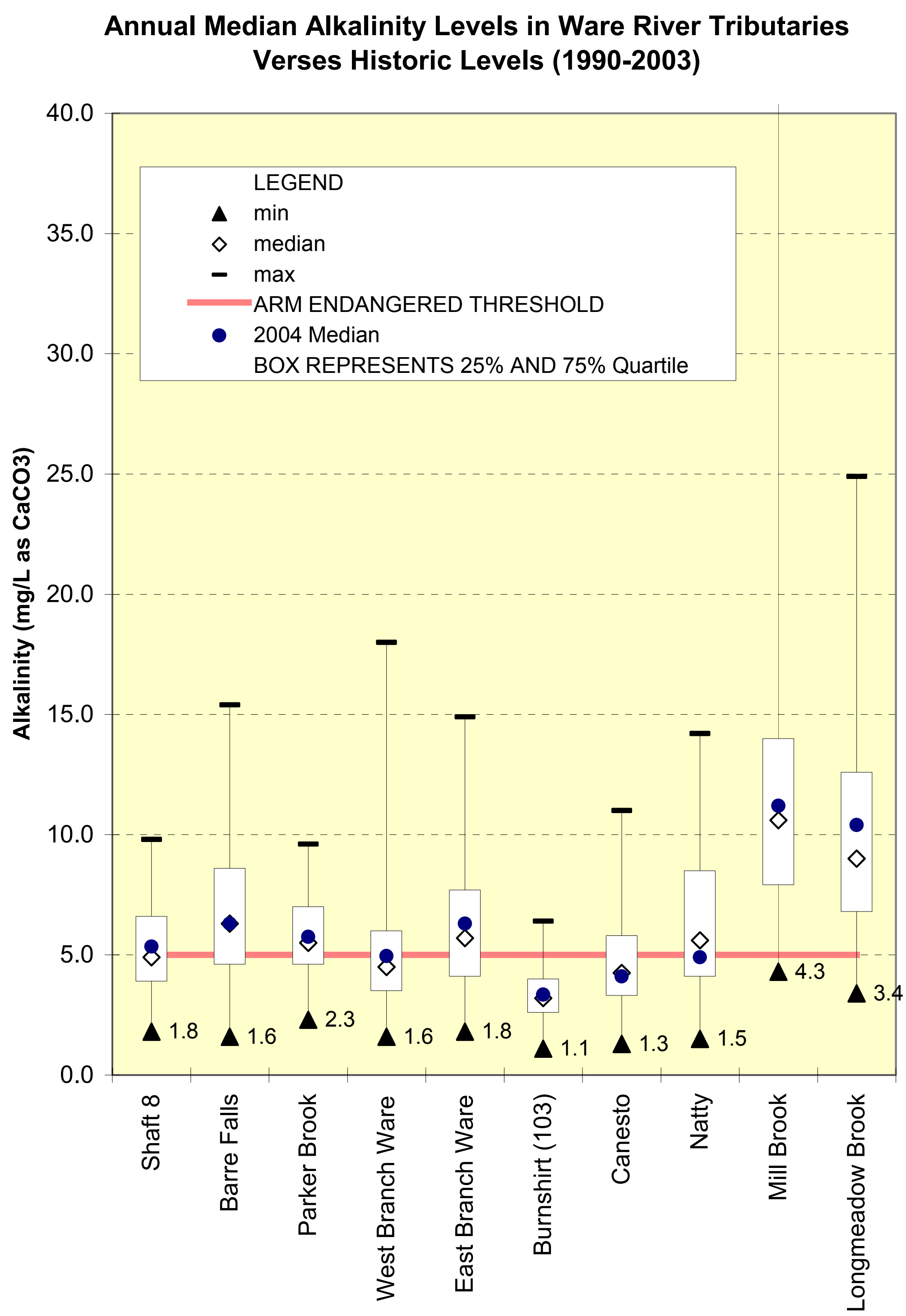
2004 Annual Median Fecal Coliform Levels in Ware River Tributaries Verses Historic Levels (1990-03)



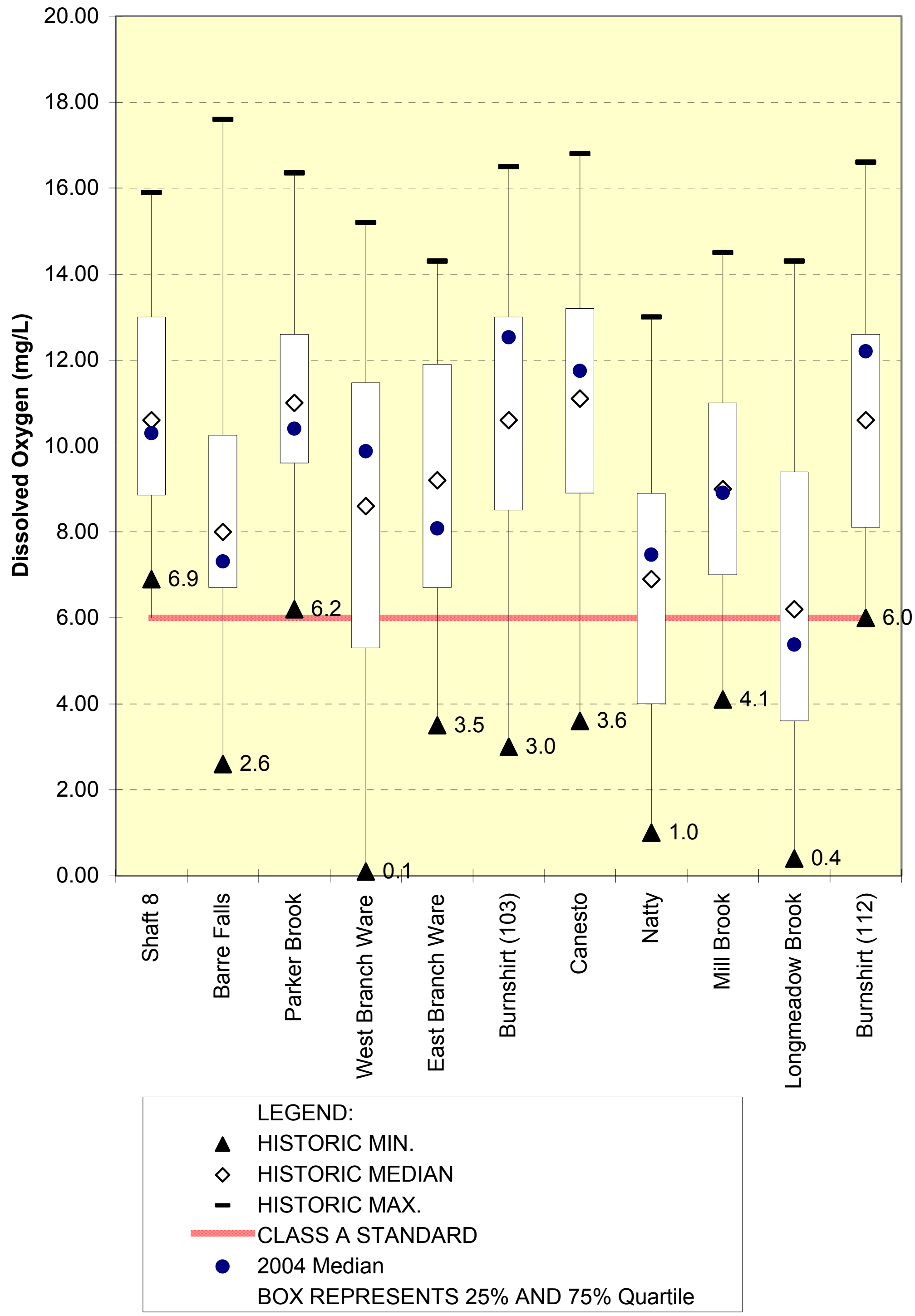
Annual Median Specific Conductance Levels in Ware River Tributaries Verses Historic Levels (1990-2003)



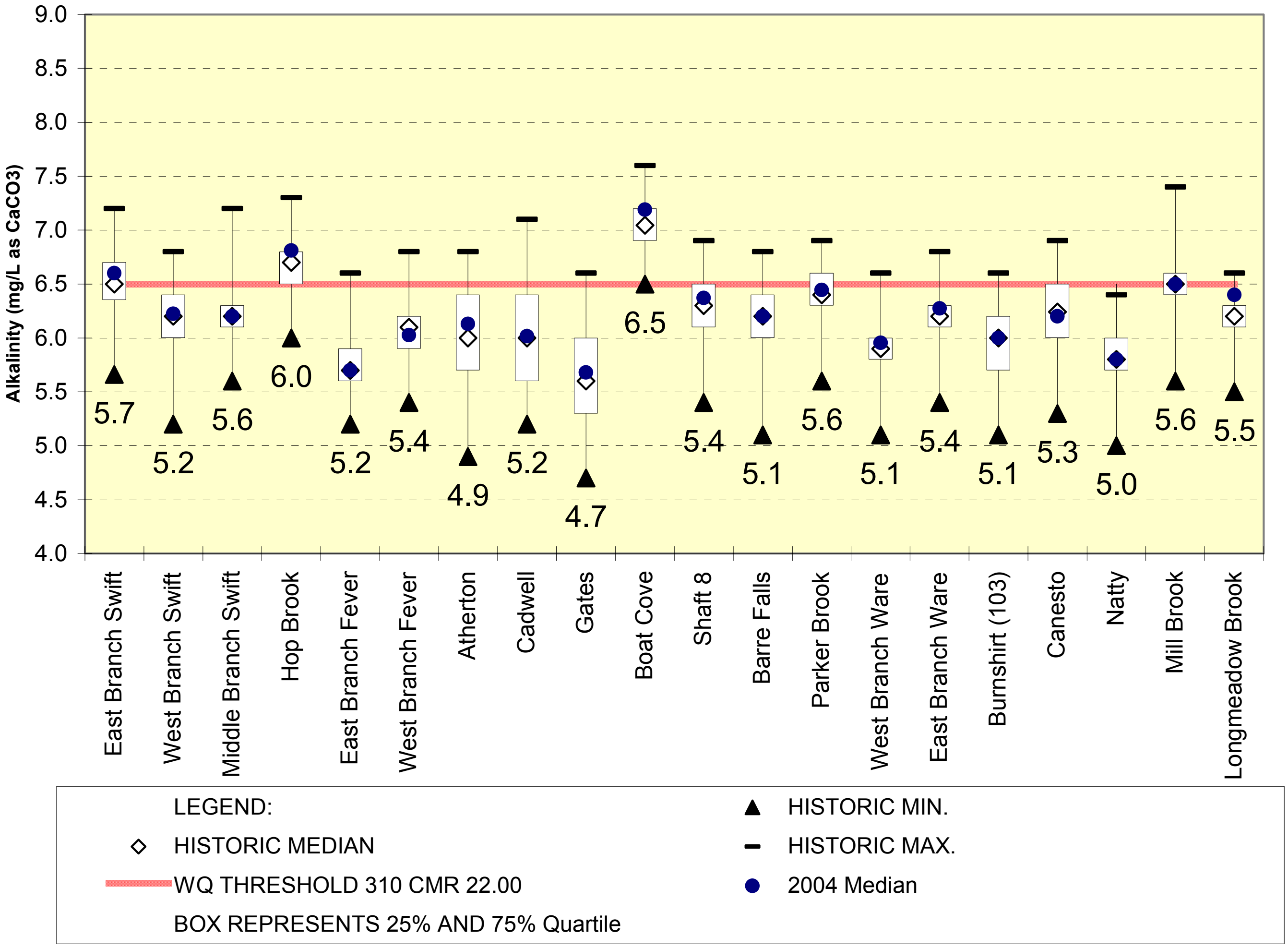

Annual Median Turbidity Levels in Ware River Tributaries
Verses Historic Levels (1990-2003)
Turbidity (NTU)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
4.00
4.20
4.50
7.50
4.50
2.50
3.50
6.80
8.50
7.30
Shaft 8
Barre Falls
Parker Brook
West Branch Ware
East Branch Ware
Burnshirt (103)
Canesto
Natty
Mill Brook
Longmeadow Brook
LEGEND:
HISTORIC MEDIAN
WQ STANDARD
BOX REPRESENTS 25% AND 75% Quartile
HISTORIC MIN.
HISTORIC MAX.
2004 Median

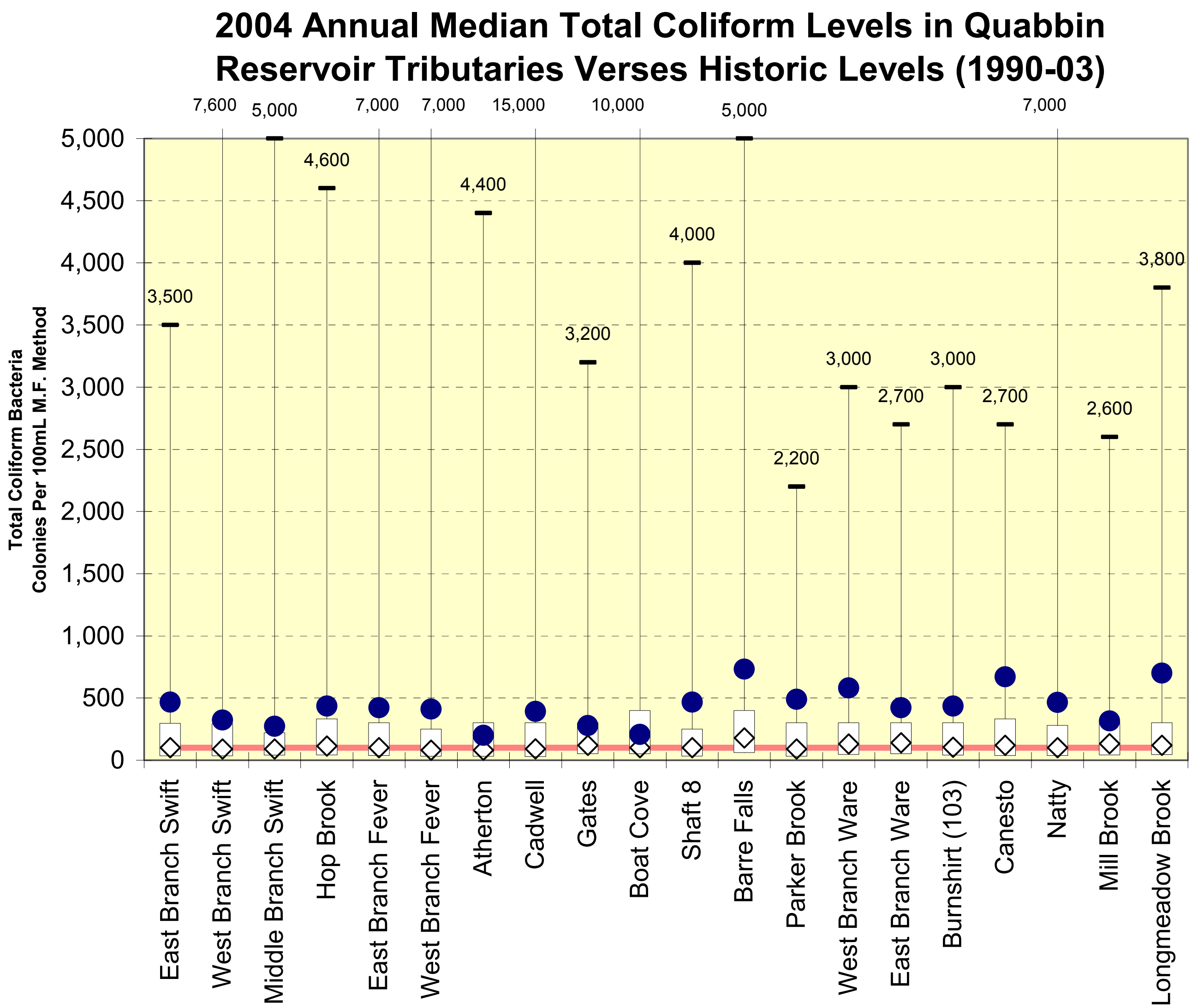

Annual Median Alkalinity Levels in Ware River Tributaries
Verses Historic Levels (1990-2003)
Alkalinity (mg/L as CaCO3)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
LEGEND
min
median
max
ARM ENDANGERED THRESHOLD
2004 Median
BOX REPRESENTS 25% AND 75% Quartile
1.8
1.6
2.3
1.6
1.8
1.1
1.3
1.5
4.3
3.4
Shaft 8
Barre Falls
Parker Brook
West Branch Ware
East Branch Ware
Burnshirt (103)
Canesto
Natty
Mill Brook
Longmeadow Brook

2004 Annual Median Dissolved Oxygen Levels in Ware River Tributaries Verses Historic Levels (1990-2003)



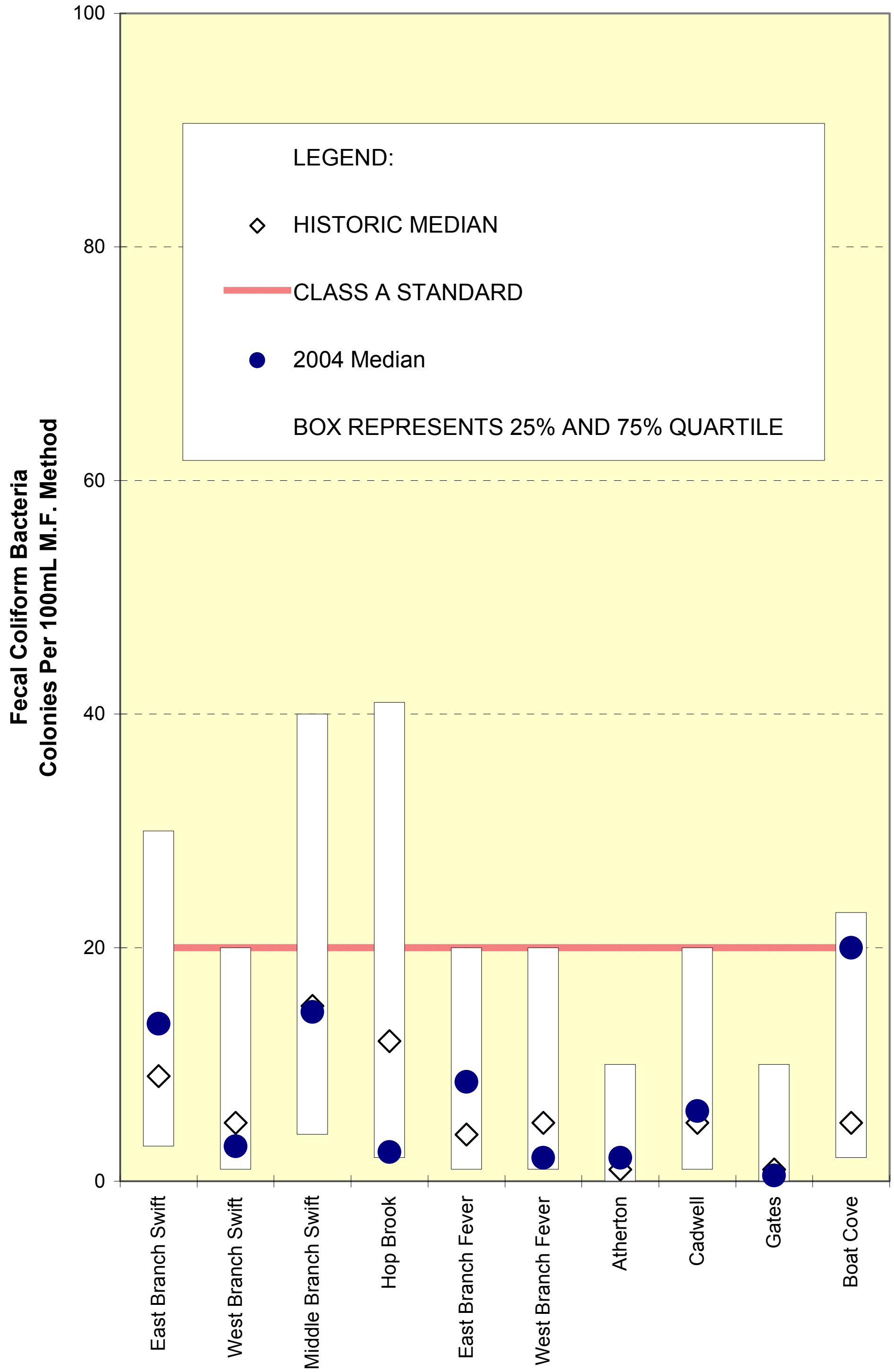
Annual Median pH Levels in Quabbin Reservoir and Ware River Tributaries Verses Historic Levels (1990-2003)



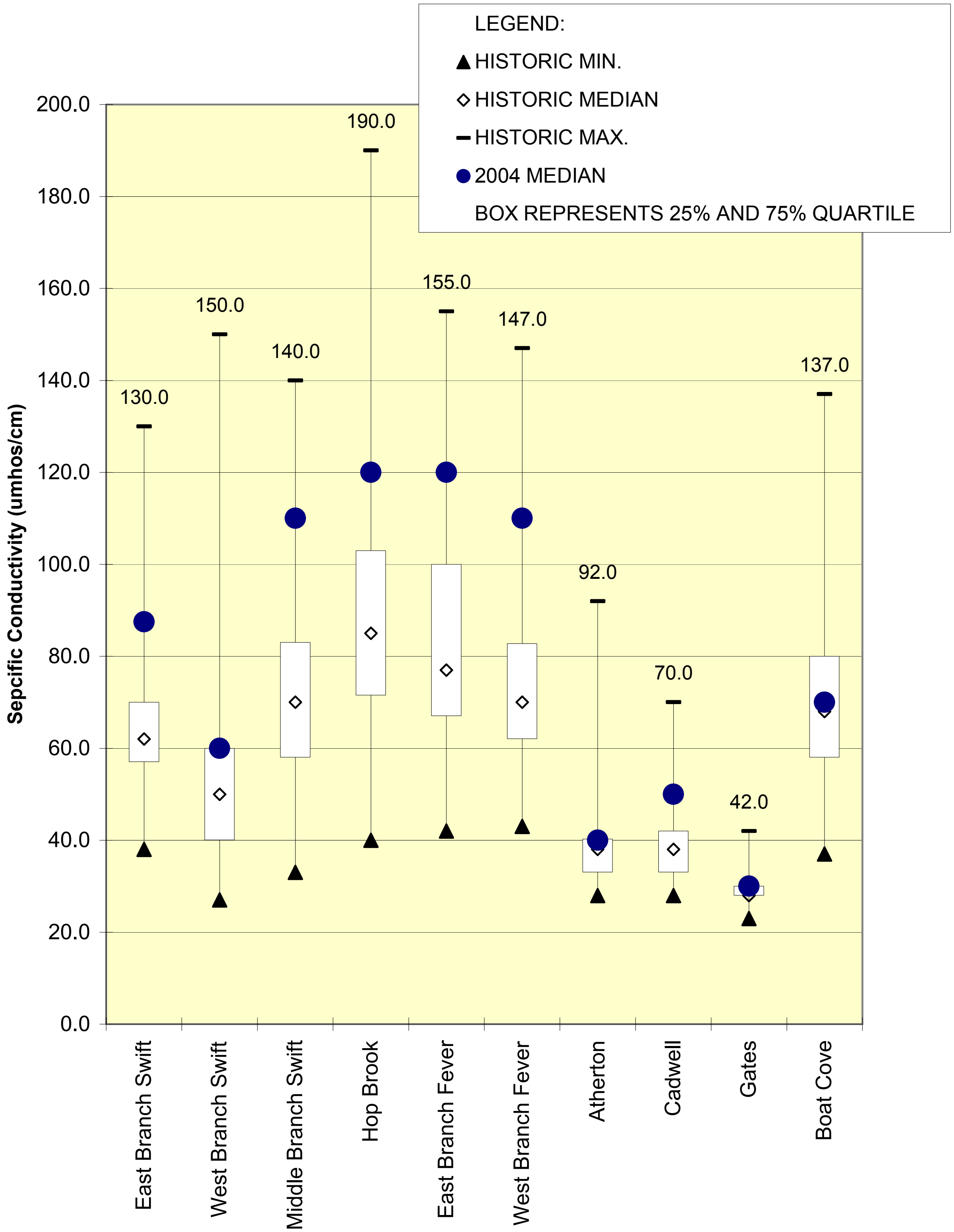


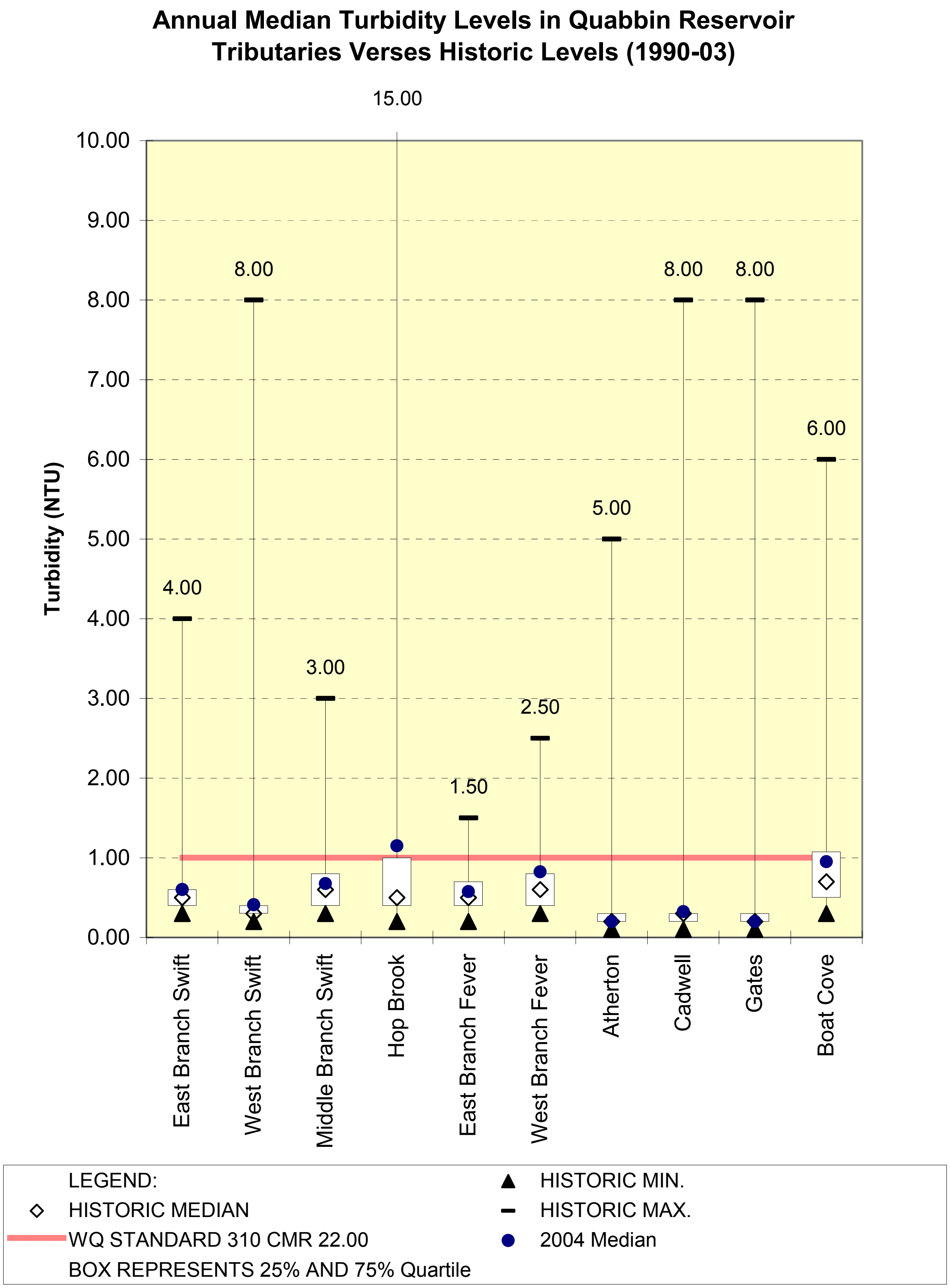
2004 Annual Median Total Coliform Levels in Quabbin Reservoir Tributaries Verses Historic Levels (1990-03)
Total Coliform Bacteria Colonies Per 100mL M.F. Method
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
3,500
7,600
5,000
4,600
7,000
7,000
4,400
15,000
3,200
10,000
4,000
5,000
2,200
3,000
2,700
3,000
2,700
7,000
2,600
3,800
East Branch Swift
West Branch Swift
Middle Branch Swift
Hop Brook
East Branch Fever
West Branch Fever
Atherton
Cadwell
Gates
Boat Cove
Shaft 8
Barre Falls
Parker Brook
West Branch Ware
East Branch Ware
Burnshirt (103)
Canesto
Natty
Mill Brook
Longmeadow Brook

2004 Annual Median Fecal Coliform Levels in Quabbin Reservoir Tributaries Verses Historic Levels (1990-03)

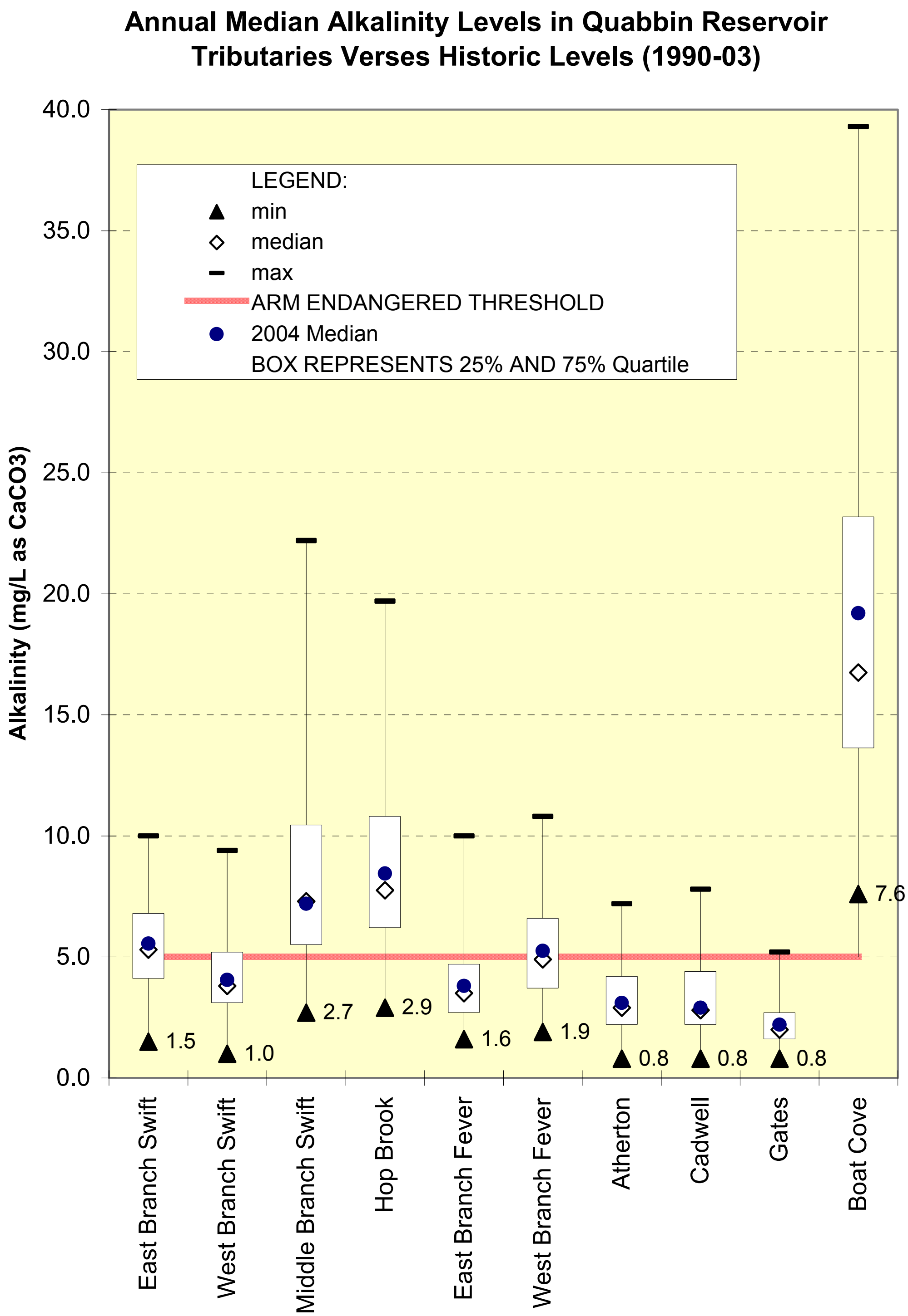


2004 Annual Median Specific Conductance Levels in Quabbin Reservoir Tributaries Verses Historic Levels (1990-03)

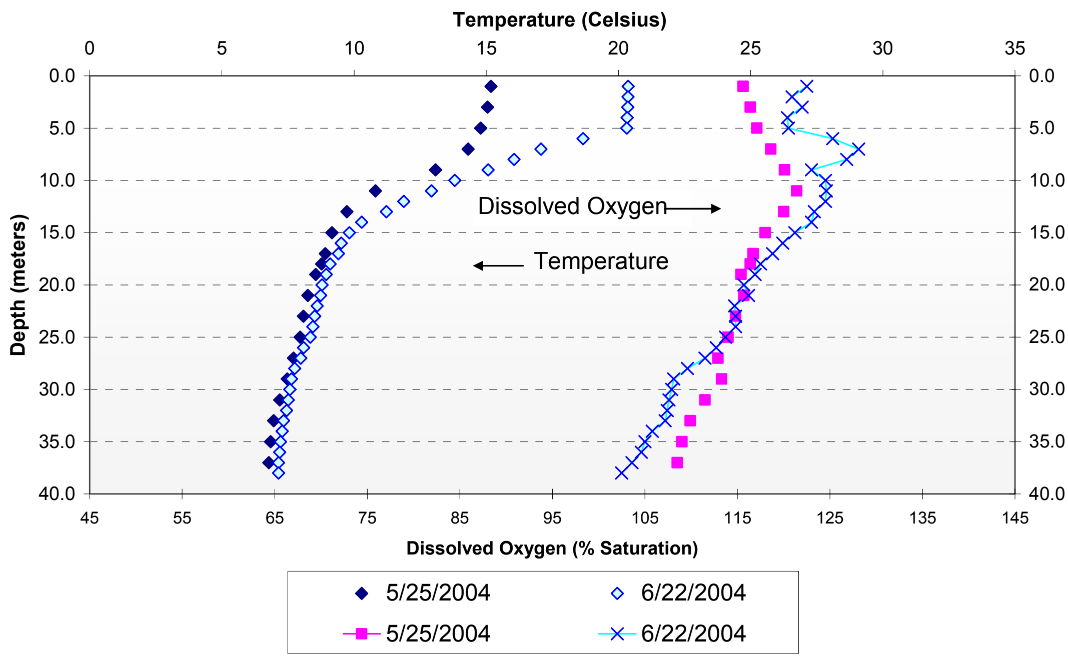




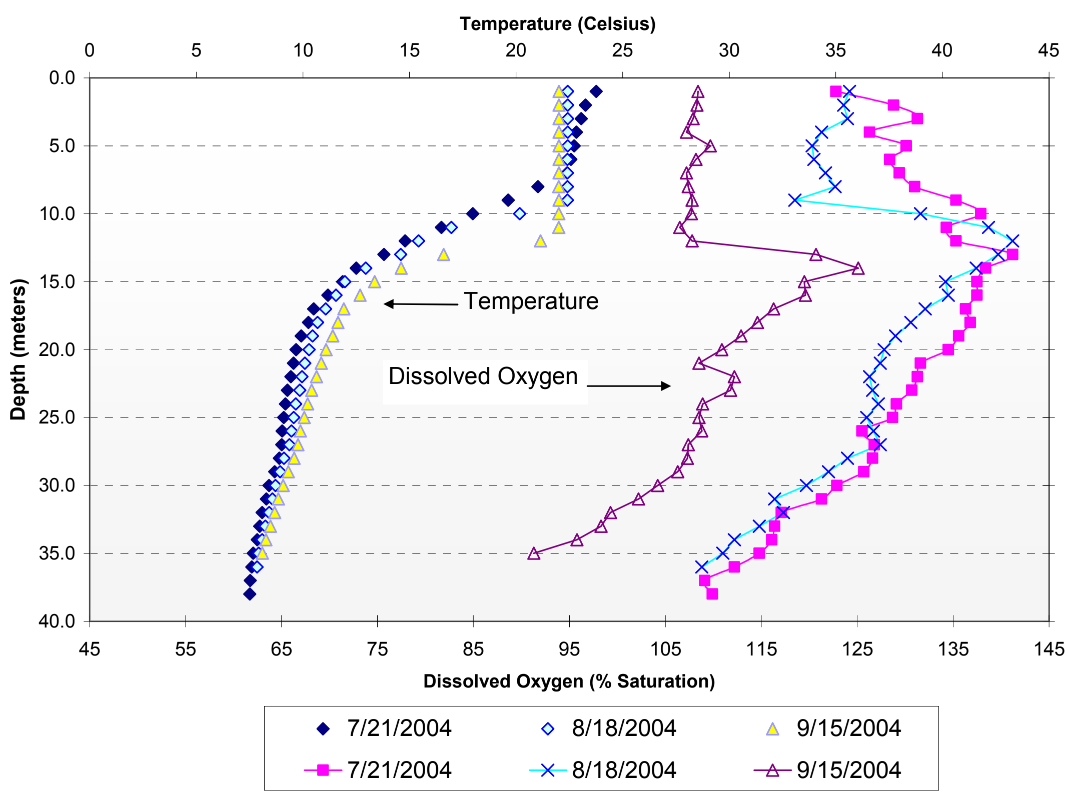
Annual Median Turbidity Levels in Quabbin Reservoir Tributaries Verses Historic Levels (1990-03)
15.00
Turbidity (NTU)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
4.00
8.00
3.00
1.50
2.50
5.00
8.00
8.00
6.00
East Branch Swift
West Branch Swift
Middle Branch Swift
Hop Brook
East Branch Fever
West Branch Fever
Atherton
Cadwell
Gates
Boat Cove
LEGEND:
HISTORIC MEDIAN
WQ STANDARD 310 CMR 22.00
BOX REPRESENTS 25% AND 75% Quartile
HISTORIC MIN.
HISTORIC MAX.
2004 Median


Annual Median Alkalinity Levels in Quabbin Reservoir
Tributaries Verses Historic Levels (1990-03)
LEGEND:
min
median
max
ARM ENDANGERED THRESHOLD
2004 Median
BOX REPRESENTS 25% AND 75% Quartile
Alkalinity (mg/L as CaCO3)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1.5
1.0
2.7
2.9
1.6
1.9
0.8
0.8
0.8
7.6
East Branch Swift
West Branch Swift
Middle Branch Swift
Hop Brook
East Branch Fever
West Branch Fever
Atherton
Cadwell
Gates
Boat Cove

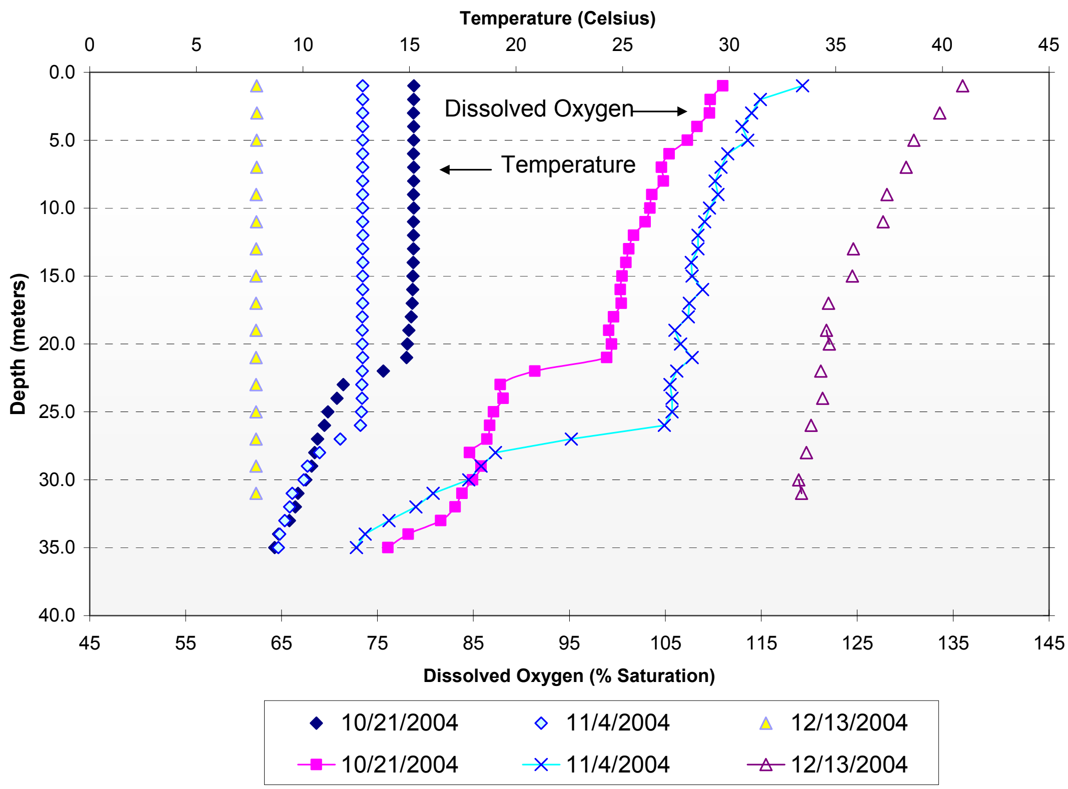
Quabbin Reservoir Site 202 - CY 2004
Temperature and Dissovled Oxygen Profiles (May - June)



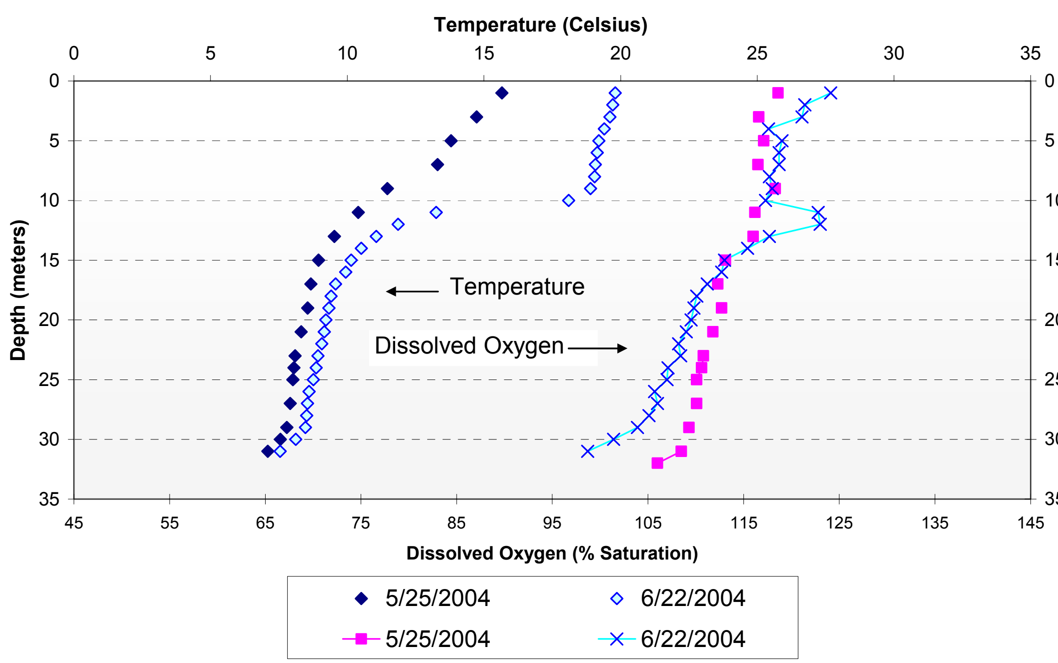
Quabbin Reseervoir Site 202 - CY 2004
Temperature and Dissolved Oxygen Profiles (July - September)



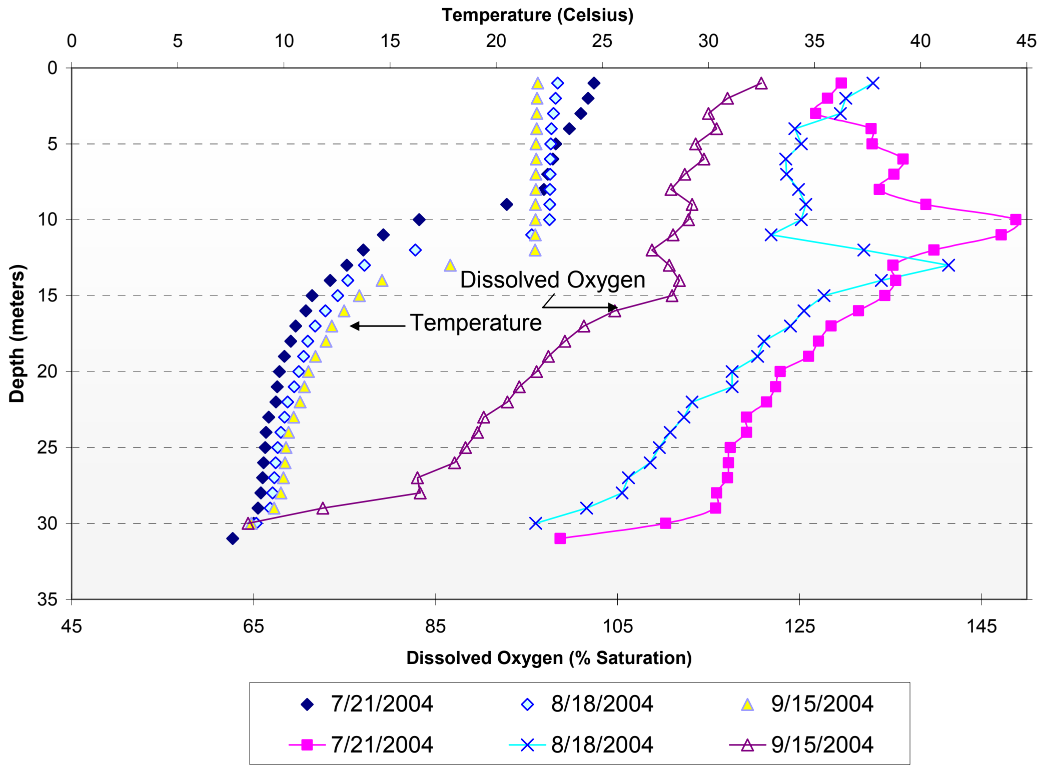
Quabbin Reservoir Site 202 - CY 2004
Temperature and Dissolved Oxygen Profiles (October - December)



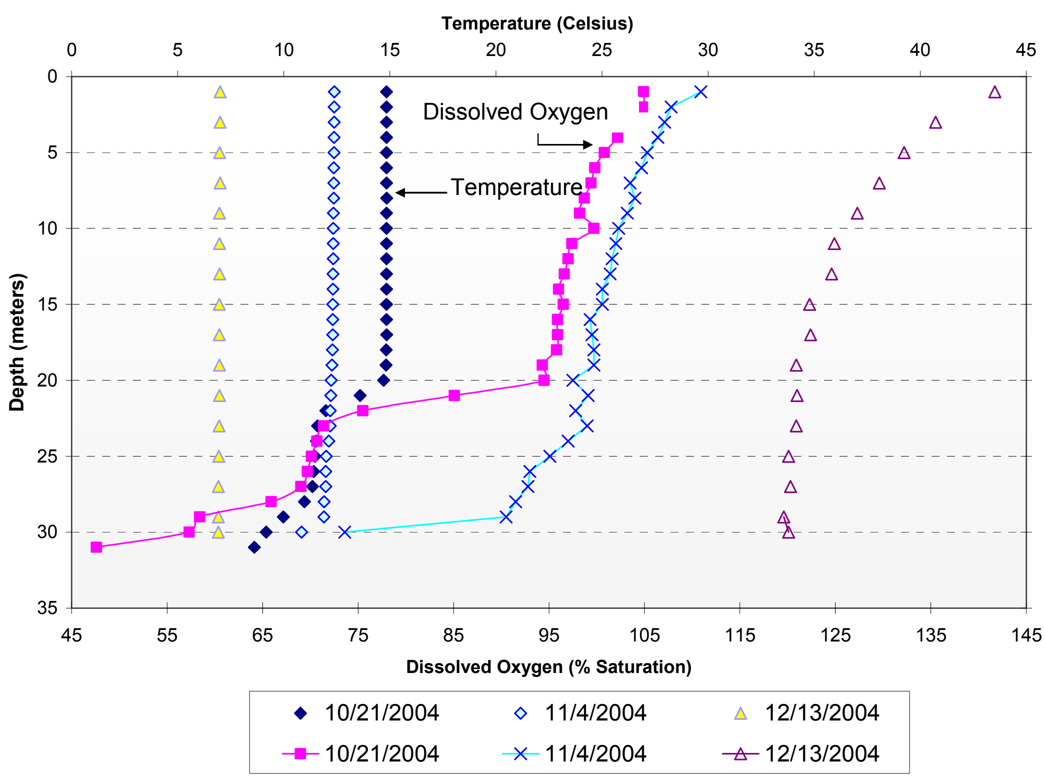
Quabbin Reservoir Site 206 - CY 2004
Temperature and Dissovled Oxygen Profiles (May - June)

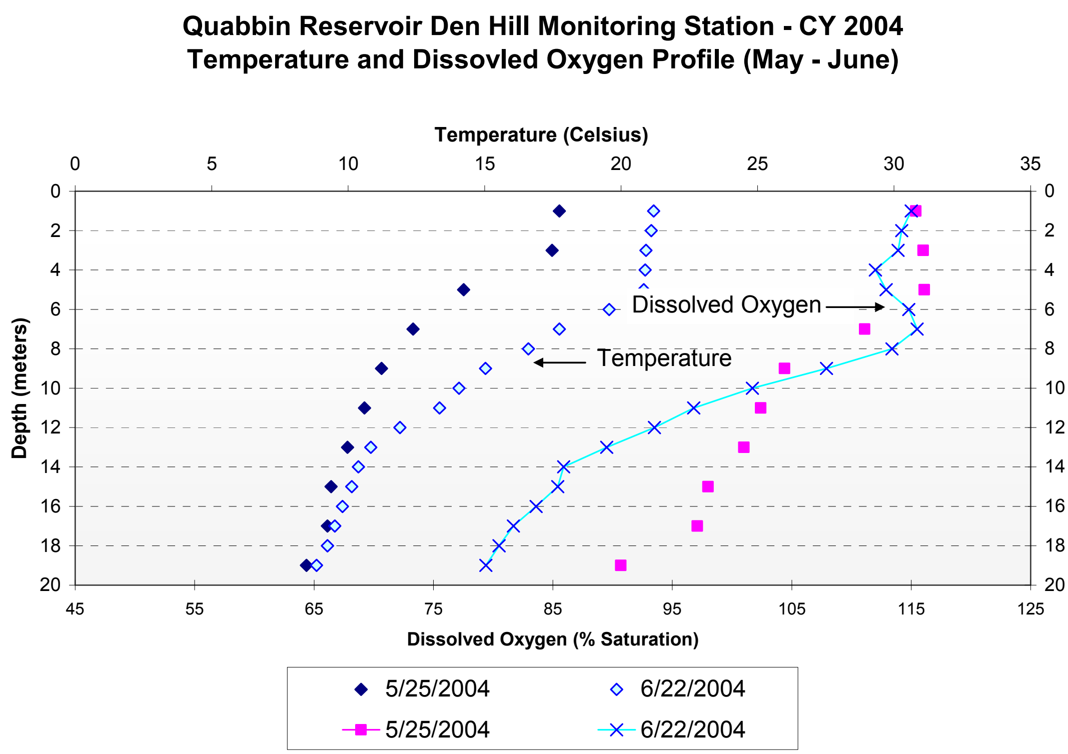


Quabbin Reservoir Site 206 - CY 2004
Temperature and Dissolved Oxygen Profiles (July - September)

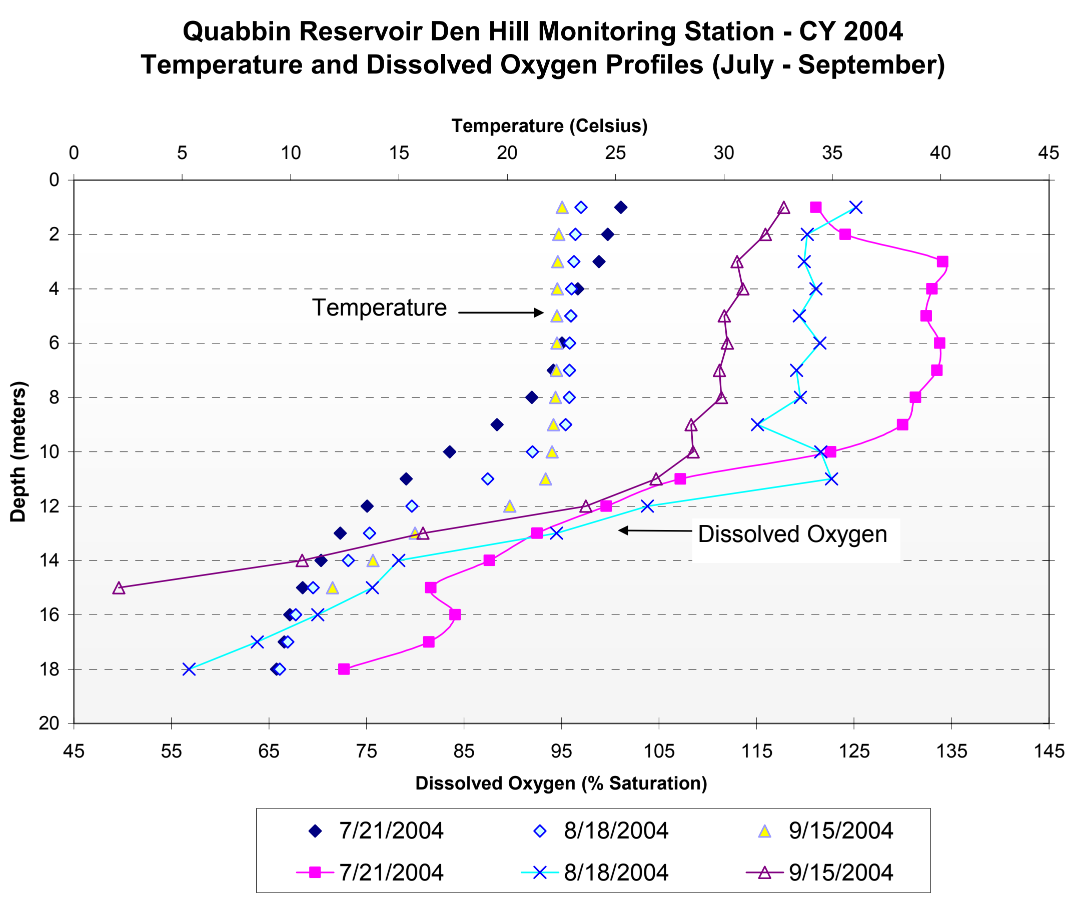


Quabbin Reservoir Site 206 - CY 2004
Temperature and Dissolved Oxygen Profiles (October - December)



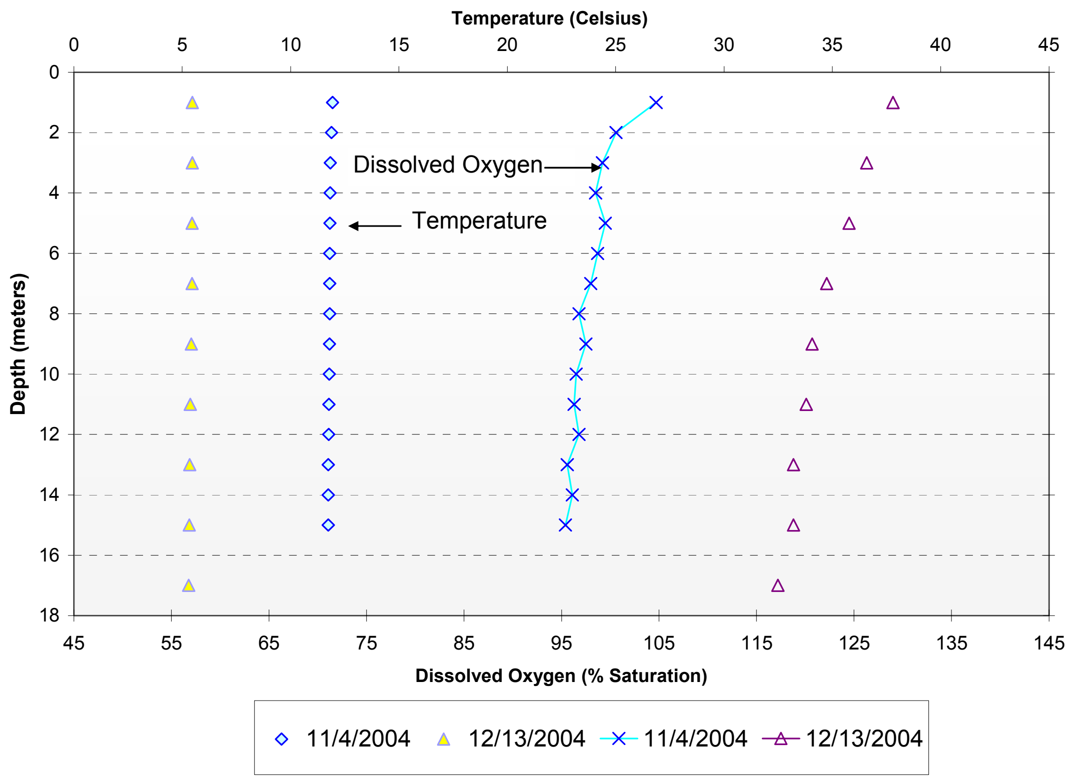


Quabbin Reservoir Den Hill Monitoring Station - CY 2004
Temperature and Dissovled Oxygen Profile (May - June)
Temperature (Celsius)
0
5
10
15
20
25
30
35
Depth (meters)
Dissolved Oxygen
Temperature
Dissolved Oxygen (% Saturation)
45
55
65
75
85
95
105
115
125
5/25/2004
6/22/2004
5/25/2004
6/22/2004



Quabbin Reservoir Den Hill Monitoring Station - CY 2004
Temperature and Dissolved Oxygen Profiles (July - September)
Temperature (Celsius)
0
5
10
15
20
25
30
35
40
45
Depth (meters)
Temperature
Dissolved Oxygen
Dissolved Oxygen (% Saturation)
45
55
65
75
85
95
105
115
125
135
145
7/21/2004
8/18/2004
9/15/2004
7/21/2004
8/18/2004
9/15/2004

Quabbin Reservoir Den Hill Monitoring Station - CY 2004 Temperature and Dissolved Oxygen Profiles (October - December)

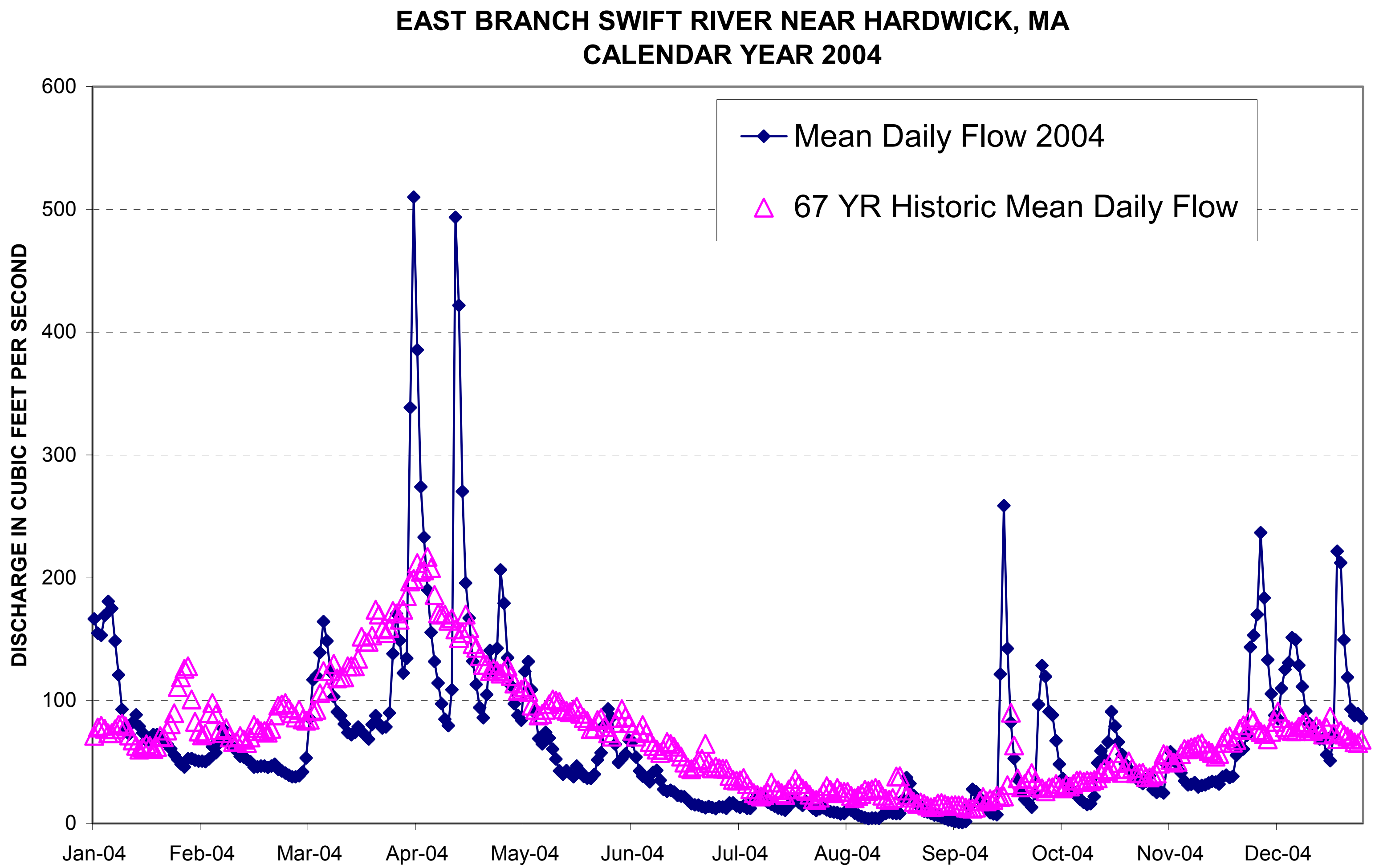


APPENDIX C

Tributary Flow Data

EAST BRANCH SWIFT RIVER NEAR HARDWICK - DISCHARGE, CUBIC FEET PER SECOND (DD 01),
JANUARY 1, 2004 TO DECEMBER 31, 2004
DAILY MEAN VALUES

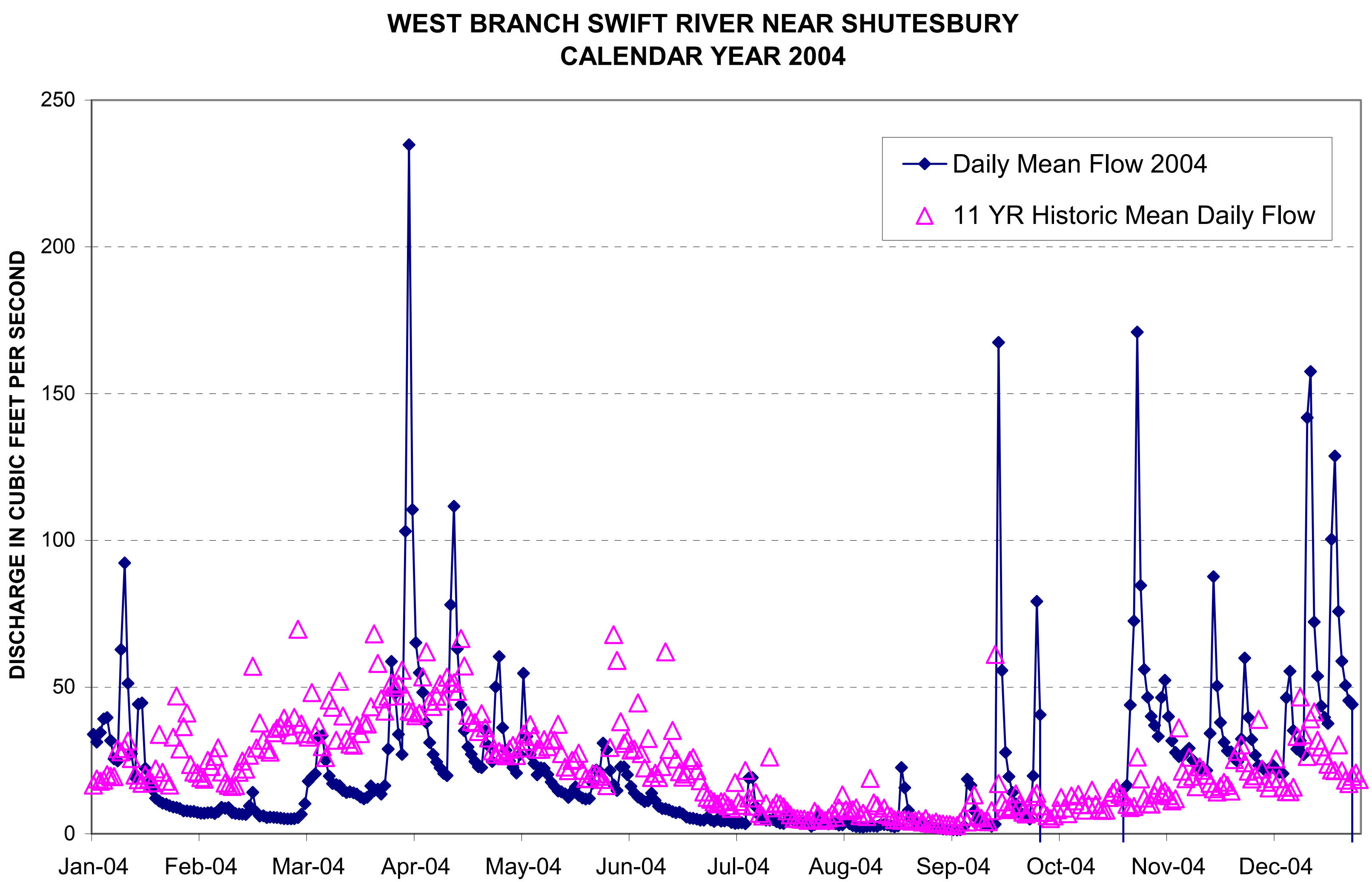
DATE	Jan 2004	Feb 2004	Mar 2004	Apr 2004	May 2004	Jun 2004	Jul 2004	Aug 2004	Sep 2004	Oct 2004	Nov 2004	Dec 2004
1	166.6	50.6	42.0	338.7	97.5	52.7	12.4	9.2	5.1	119.6	27.5	170.1
2	154.9	50.3	53.3	510.0	88.1	56.6	16.8	8.8	3.9	91.1	25.2	236.7
3	153.2	52.4	85.5	385.5	84.2	67.7	16.8	7.6	2.8	88.3	26.6	183.6
4	169.5	62.5	117.0	274.2	123.7	66.8	14.2	8.2	2.3	67.5	24.8	133.2
5	180.9	57.4	120.3	233.0	131.9	53.9	12.9	11.4	1.6	48.4	47.5	105.6
6	175.2	65.6	139.1	190.2	108.9	42.7	14.2	10.8	0.9	36.7	58.4	88.1
7	148.5	77.1	164.3	155.6	90.1	38.3	12.4	8.4	0.7	32.9	55.5	85.2
8	120.8	69.8	148.7	132.0	69.0	37.1	12.3	6.7	1.6	29.1	48.3	109.9
9	92.8	64.4	123.3	114.4	64.7	33.8	19.3	5.7	13.3	25.0	41.2	125.4
10	77.2	61.6	103.2	97.4	74.1	41.7	23.2	4.6	27.8	22.8	34.6	130.8
11	72.7	59.1	90.8	84.8	69.6	43.2	23.5	4.0	25.9	19.6	31.4	151.4
12	82.2	54.6	87.7	79.7	60.5	35.2	19.2	4.3	20.8	17.1	31.8	149.5
13	88.4	54.1	81.0	108.9	52.5	27.7	17.2	4.4	16.4	15.3	33.4	128.9
14	79.0	52.1	73.9	493.6	42.7	26.1	15.5	4.2	12.0	15.9	29.6	111.5
15	73.7	50.3	72.3	421.8	40.0	27.0	13.9	6.5	8.8	21.8	30.9	91.6
16	67.4	45.9	74.0	270.3	43.1	25.7	12.4	8.2	7.7	49.3	31.3	81.5
17	67.5	46.0	78.5	195.7	40.6	22.8	11.7	9.3	7.0	59.1	32.8	78.0
18	72.3	46.8	74.8	167.2	38.0	22.3	10.9	8.3	121.7	52.6	34.2	70.4
19	72.5	46.8	71.8	132.1	46.8	21.8	14.1	8.0	258.8	66.2	33.7	68.6
20	69.4	45.7	68.7	113.2	42.7	18.9	19.4	8.1	142.5	91.0	32.0	68.9
21	66.7	46.8	80.5	94.4	38.2	16.0	19.1	19.5	82.3	79.1	38.0	55.9
22	64.5	48.3	87.8	86.1	36.8	15.0	16.9	37.4	52.9	66.2	39.2	51.0
23	60.8	43.8	81.2	105.0	36.7	15.0	14.8	32.5	35.7	56.1	37.3	73.1
24	55.8	42.7	77.7	140.9	40.0	13.6	18.1	22.8	25.0	48.6	38.5	221.7
25	52.1	41.0	78.6	124.2	51.8	12.6	15.2	16.8	19.6	44.6	55.4	212.1
26	48.3	39.4	89.9	142.5	57.4	13.7	12.2	12.7	16.7	41.0	62.4	149.5
27	46.0	37.9	138.3	206.5	80.4	12.9	10.5	10.1	13.2	37.7	60.5	118.9
28	52.6	37.9	170.7	179.2	93.4	12.1	12.0	9.2	24.3	34.2	71.8	93.0
29	52.8	38.8	148.9	134.9	86.5	13.5	12.8	8.1	96.7	32.5	143.5	87.8
30	51.5		122.5	112.3	64.6	13.3	11.0	6.9	128.6	34.0	153.1	89.3
31	50.7		134.6		49.5		9.6	6.4		38.6		85.5
MAX	180.9	77.1	170.7	510.0	131.9	67.7	23.5	37.4	258.8	119.6	153.1	236.7
MIN	46.0	37.9	42.0	79.7	36.7	12.1	9.6	4.0	0.7	15.3	24.8	51.0
MEAN	89.9	51.8	99.4	194.1	65.9	30.0	15.0	10.6	39.2	47.8	47.0	116.3
DEPARTURE FROM NORM	10.1	-28.1	-35.6	33.1	-25.7	-31.1	-13.7	-12.4	13.5	10.0	-14.8	40.6
STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1937 - 2003												
WY 37-03 MEAN	79.8	79.9	135	161	91.6	61.1	28.7	23	25.7	37.8	61.8	75.7
MIN	5.3	18.5	46.4	34.8	30.5	6.87	3.23	0	0	0.72	4.17	15.6
MAX	240	207	266	420	189	175	179	127	390	155	177	264


EAST BRANCH SWIFT RIVER NEAR HARDWICK, MA
CALENDAR YEAR 2004
DISCHARGE IN CUBIC FEET PER SECOND
0
100
200
300
400
500
600
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Mean Daily Flow 2004
67 YR Historic Mean Daily Flow

WEST BRANCH SWIFT RIVER - DISCHARGE, CUBIC FEET PER SECOND (DD 01)
JANUARY 1, 2004 TO DECEMBER 31, 2004
DAILY MEAN VALUES

DATE	Jan 2004	Feb 2004	Mar 2004	Apr 2004	May 2004	Jun 2004	Jul 2004	Aug 2004	Sep 2004	Oct 2004	Nov 2004	Dec 2004
1	33.9	7.1	6.7	234.8	22.6	22.8	4.4	4.0	1.9	26.8	40.0	26.8
2	31.3	7.0	10.3	110.5	20.7	22.8	4.6	3.4	1.6	21.9	37.0	23.3
3	34.5	7.2	17.9	65.1	26.9	20.2	3.8	3.0	1.5	19.2	33.2	22.9
4	39.1	7.3	19.3	54.9	54.7	16.2	3.5	3.0	1.6	16.5	46.5	21.4
5	39.6	6.9	20.5	48.2	33.2	14.0	3.7	5.0	1.4	12.8	52.4	21.8
6	31.8	7.6	33.2	37.9	27.0	12.5	3.8	3.4	1.3	10.9	40.0	23.4
7	25.6	9.1	33.5	31.1	24.0	11.8	3.4	2.9	1.4	10.3	31.7	21.7
8	24.8	8.7	25.0	27.1	20.1	11.0	19.0	2.5	2.6	9.8	27.7	21.0
9	62.8	8.9	19.6	24.5	22.5	11.2	19.2	2.3	18.6	8.9	26.3	20.5
10	92.3	7.2	17.1	22.5	22.3	13.8	9.3	2.3	16.5	8.3	26.5	46.4
11	51.3	7.0	16.7	20.5	20.2	11.3	6.3	2.5	7.8	7.2	28.0	55.4
12	27.3	6.8	16.5	19.9	17.6	9.4	5.0	2.6	5.0	6.8	29.1	35.2
13	19.2	6.7	14.7	78.1	16.1	8.6	4.7	2.6	3.9	6.4	25.1	28.9
14	44.2	6.6	14.0	111.6	14.6	8.5	4.7	2.5	3.0	*	23.4	31.7
15	44.6	9.5	14.3	63.0	14.3	8.2	4.8	3.2	3.0	*	22.4	27.0
16	22.3	14.1	14.0	44.0	13.6	7.5	4.1	3.2	2.5	*	21.9	141.8
17	17.3	7.4	13.6	35.1	12.4	7.2	3.7	3.1	3.2	*	21.6	157.6
18	15.1	6.1	12.5	29.6	14.3	7.4	3.5	2.7	167.5	*	34.3	72.2
19	12.2	6.1	12.0	27.2	16.0	6.8	6.7	2.4	55.7	*	87.6	53.7
20	11.1	5.5	12.5	24.6	13.1	5.7	5.8	2.7	27.8	*	50.4	43.6
21	10.5	5.7	16.4	22.8	12.2	5.4	4.5	22.6	19.5	*	37.9	39.7
22	10.1	5.7	14.6	22.6	11.9	5.2	3.9	15.8	14.1	*	31.2	37.6
23	9.6	5.5	15.2	35.1	12.0	5.0	3.9	8.0	10.2	*	28.3	100.4
24	9.1	5.4	13.6	30.0	17.2	4.6	3.7	5.1	7.4	15.2	27.9	128.8
25	9.0	5.2	16.4	24.7	21.7	4.6	3.6	3.9	6.5	16.5	25.6	75.7
26	8.6	5.1	28.9	50.1	21.3	5.5	2.5	3.4	5.9	43.9	24.6	58.8
27	7.8	5.1	58.8	60.4	30.9	4.7	3.1	3.2	5.0	72.5	32.3	50.6
28	7.8	5.1	47.8	36.2	28.6	4.2	6.1	2.8	19.7	170.9	59.9	45.4
29	7.6	5.5	33.9	28.4	21.6	4.9	4.4	2.6	79.2	84.7	39.7	44.0
30	7.6		27.0	24.8	16.7	4.3	3.7	2.3	40.5	56.0	32.1	
31	7.3		103.1		14.8		3.3	2.1		46.5		
MAX	**92.3**	**14.1**	**103.1**	**234.8**	**54.7**	**22.8**	**19.2**	**22.6**	**167.5**	**170.9**	**87.6**	**157.6**
MIN	**7.3**	**5.1**	**6.7**	**19.9**	**11.9**	**4.2**	**2.5**	**2.1**	**1.3**	**6.4**	**21.6**	**20.5**
MEAN	**25.0**	**6.9**	**23.2**	**48.2**	**20.5**	**9.5**	**5.4**	**4.2**	**17.9**	**32.0**	**34.8**	**50.9**
DEPART-URE FROM NORM	**-1.0**	**-18.1**	**-20.8**	**7.2**	**-5.5**	**-15.5**	**-3.6**	**-2.8**	**7.9**	**20.0**	**16.8**	**28.9**
	STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1995 - 2003											
wy 95-03 MEAN	26	25	44	41	26	25	9	7	10	12	18	22
MIN	2.61	7.15	19.7	19.3	11.6	3.73	1.98	1.7	1.02	1.84	1.72	4.11
MAX	51.0	40.9	60.1	77.7	44.1	52.8	24.3	29.3	52.9	29.5	39.2	75.3

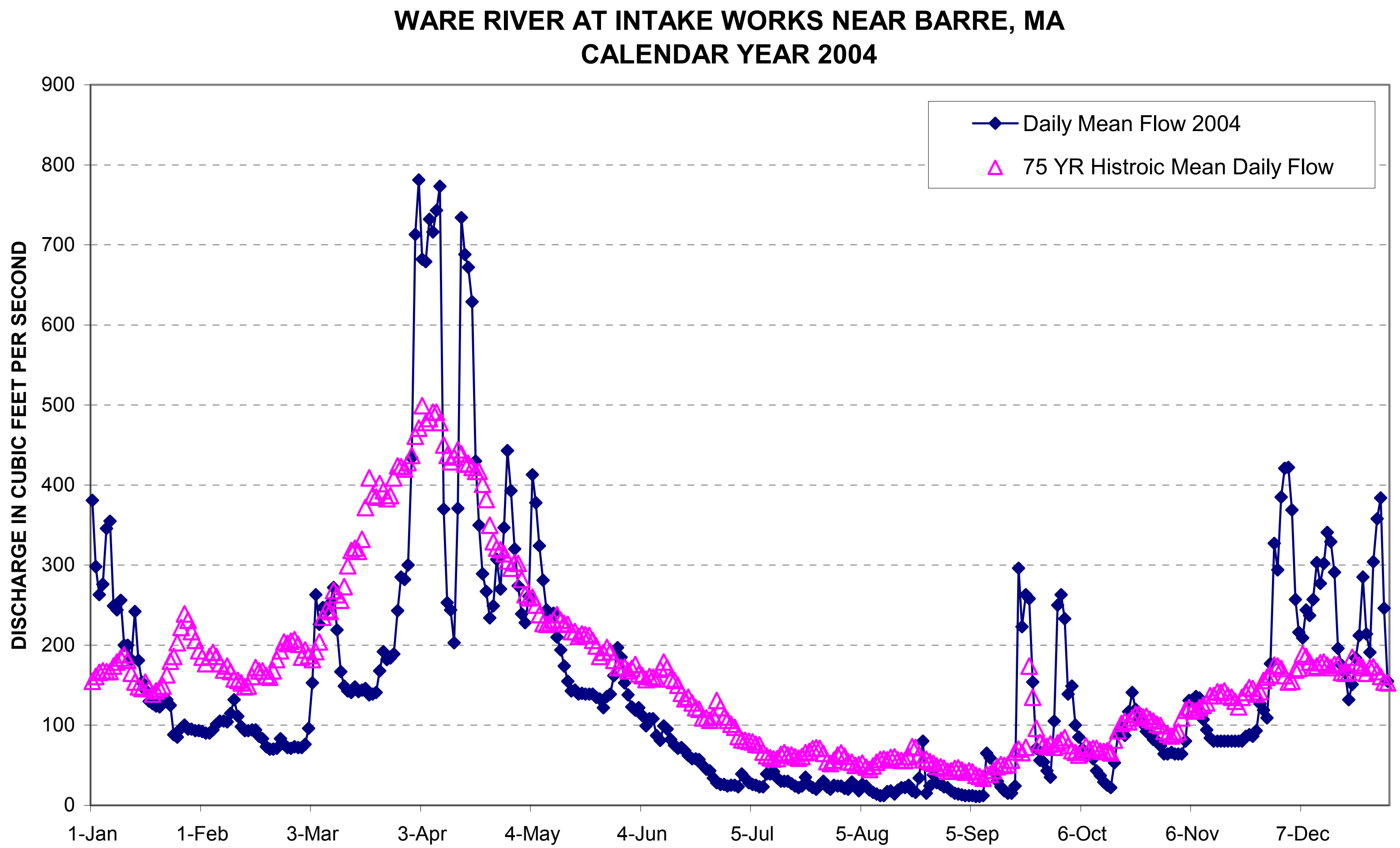
*Missing Data



WEST BRANCH SWIFT RIVER NEAR SHUTESBURY
CALENDAR YEAR 2004
DISCHARGE IN CUBIC FEET PER SECOND
250
200
150
100
50
0
Daily Mean Flow 2004
11 YR Historic Mean Daily Flow
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04

WARE RIVER AT INTAKE WORKS - DISCHARGE, CUBIC FEET PER SECOND (DD 01),
JANUARY 1, 2004 TO DECEMBER 31, 2004
DAILY MEAN VALUES

DATE	Jan 2004	Feb 2004	Mar 2004	Apr 2004	May 2004	Jun 2004	Jul 2004	Aug 2004	Sep 2004	Oct 2004	Nov 2004	Dec 2004
1	381	92	76	713	239	123	23	20	14	233	64	385
2	298	90	96	781	228	119	39	29	13	139	64	421
3	263	90	153	682	261	122	34	25	12	149	64	422
4	276	94	263	679	413	112	28	18	12	100	80	369
5	346	101	226	732	378	99	26	26	12	85	131	257
6	355	105	247	716	324	108	25	24	11	70	132	216
7	249	105	243	743	281	108	23	19	11	61	136	209
8	244	104	252	773	244	87	23	16	12	65	134	244
9	256	115	272	370	237	81	39	14	65	58	107	237
10	200	132	219	253	240	99	39	12	59	43	94	257
11	200	111	167	244	210	95	42	12	43	37	84	303
12	182	98	149	203	194	82	34	17	30	29	80	277
13	242	93	143	371	174	75	30	18	23	25	80	302
14	181	93	141	734	155	71	30	14	18	22	80	341
15	154	94	148	688	143	72	30	19	15	53	80	329
16	144	94	142	672	144	68	27	22	15	88	80	291
17	130	86	144	629	139	62	24	22	24	97	80	196
18	127	83	146	430	140	58	22	25	296	87	80	175
19	124	73	138	350	139	58	24	18	223	117	80	166
20	123	70	139	289	139	57	35	16	263	141	80	132
21	132	70	141	267	139	50	25	34	258	120	86	151
22	132	71	168	234	135	45	22	80	154	108	88	184
23	125	83	192	249	133	43	20	15	71	101	86	212
24	88	76	182	307	122	34	25	24	56	92	93	285
25	85	72	184	270	136	28	30	38	54	88	127	214
26	96	71	189	347	139	26	23	28	43	82	119	191
27	100	73	243	443	162	26	20	26	35	80	109	304
28	95	72	285	393	197	24	25	23	105	74	177	358
29	95	72	282	320	185	25	24	22	250	64	327	384
30	93		300	274	153	25	24	18	263	64	294	246
31	93		434		138		21	15		66		155
MAX	381	132	434	781	413	123	42	80	296	233	327	422
MIN	85	70	76	203	122	24	20	12	11	22	64	132
MEAN	180.9	89.7	196.9	471.9	195.5	69.4	27.6	22.9	82.0	85.1	110.5	264.9
DEPARTURE FROM NORM	5.9	-86.3	-125.1	64.9	-20.5	-69.6	-38.9	-31.3	18.2	-2.0	-24.5	93.9
USGS STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1928 - 2003												
wy 28-03 MEAN	175	176	322	407	216	139	66.5	54.2	63.8	87.1	135	171
MIN	17.2	37.5	118	129	73.8	18.2	9	4.94	6.12	7.86	13.9	29.1
MAX	499	488	1066	963	438	503	337	319	893	465	445	570


WARE RIVER AT INTAKE WORKS NEAR BARRE, MA
CALENDAR YEAR 2004
DISCHARGE IN CUBIC FEET PER SECOND
900
800
700
600
500
400
300
200
100
0
1-Jan
1-Feb
3-Mar
3-Apr
4-May
4-Jun
5-Jul
5-Aug
5-Sep
6-Oct
6-Nov
7-Dec
Daily Mean Flow 2004
75 YR Histroic Mean Daily Flow